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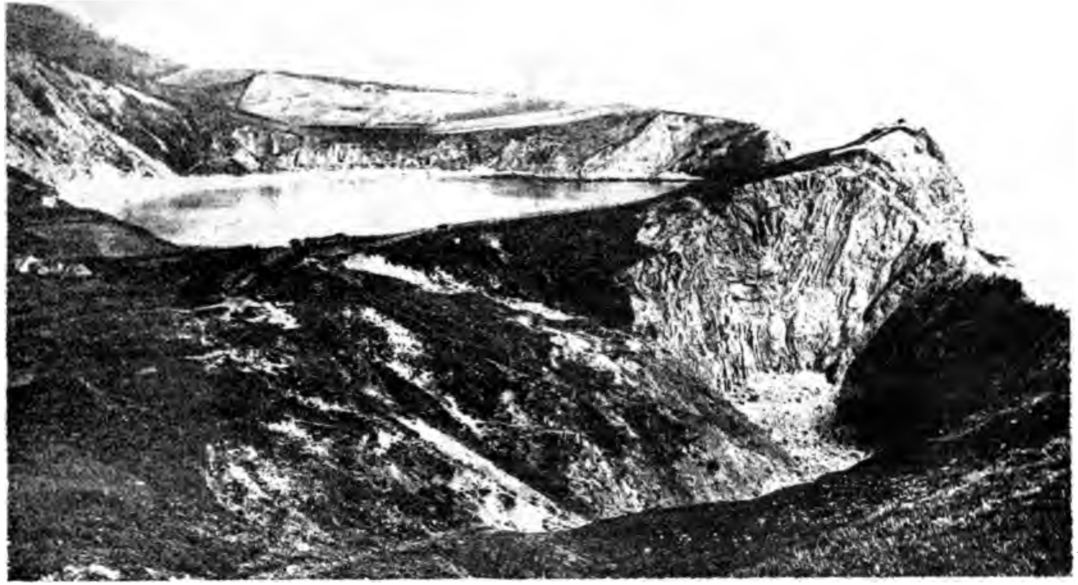

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MEMOIRS OF THE GEOLOGICAL SURVEY

ENGLAND AND WALES.

THE GEOLOGY
OF THE
ISLE OF PURBECK
AND
WEYMOUTH.

BY

AUBREY STRAHAN, M.A., F.G.S.

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PREFACE.

THE district described in the present Memoir early attracted the notice of geologists, and its admirable coast-sections have been often described. As far back as 1816 Webster furnished valuable notes and drawings regarding it which appeared in Englefield's volume on the Isle of Wight. In subsequent years Buckland, Sedgwick, Conybeare, Fitton, De la Beche, Owen, and Edward Forbes contributed their observations of the same region and quickened thereby the progress of English Geology. In more recent time the Rev. Osmond Fisher, Prof. J. F. Blake, and Mr. Hudleston have much increased our knowledge of the Purbeck, Portland, Kimmeridge, and Corallian formations. The Cretaceous rocks have been luminously described by M. Barrois, and the Quaternary and recent deposits by Prestwich. In his "Geology of Weymouth," R. Damon gave an excellent summary of all that was known at the time regarding the district. These various additions to the literature of the geology of Dorset will be found arranged in chronological order in the Bibliography at the end of this volume.

The Geological Survey maps of the districts comprising Sheets 16 and 17 of the Old Series of the One-inch Ordnance maps, were surveyed by H. W. Bristow and were published in 1850. They were followed during the next ten years by six sheets of Horizontal Sections and one sheet of Vertical Sections, also prepared by Bristow, who derived great help in his labours from the intimate local knowledge of the rocks possessed by his friend Mr. Fisher.

When the revision of the Geological Survey maps of the Isle of Wight was completed in 1888, on the scale of six inches to a mile, it was deemed advisable to continue the work into the adjacent parts of Dorset. The task of re-surveying the classic Isle of Purbeck and the region around Weymouth was entrusted to Mr. A. Strahan, who had mapped the Secondary formations of the Isle of Wight. In two years the field-work was finished as far as the top of the Chalk, and the mapping of the Tertiary deposits was subsequently completed by Mr. C. Reid. Advantage was taken of the publication of the new series of Ordnance Survey maps, and sheets 329, 341, 342, and 343 were issued coloured geologically, while sheet 328 will appear in the course of the present year. Copies of the original six-inch working maps have been made and are kept at the office for public reference, while a duplicate set, mounted as a wall-map, has been placed in the Museum of Practical Geology, by the side of the corresponding large map of the Isle of Wight.

Though all these detailed observations by the Survey have been published at intervals since 1850, no special descriptive Memoir of the Isle of Purbeck has hitherto been prepared. In 1895, however, a full account of the formations of the district up to the top of the Purbeck series was given by Mr. H. B. Woodward in Vols. IV. and V. of the Geological Survey Memoir on the Jurassic Rocks of Britain. But there appeared to be still ample room for a more local and detailed Memoir which, embracing the Cretaceous, Tertiary and Post-tertiary formations might serve as a general guide to this most instructive and frequently visited part of the southern coast of England. Accordingly Mr. Strahan was instructed to prepare the Memoir which is now issued. While relying mainly on his own personal observations on the ground, he has also availed himself of the materials gathered together by Mr Woodward for the volumes on the Jurassic rocks.

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In the preparation of the Maps and Memoir the question had to be considered at what horizon the boundary should be drawn between the Jurassic and Cretaceous systems. There can be no doubt that the present practice, which includes the Purbeck series in the Jurassic, and the Wealden in the Cretaceous formations, divides two groups of strata which are closely linked together. If on the other hand, the Wealden groups, as has been urgently demanded, should be united with the Jurassic system, the objection would be strongly maintained that in other parts of England what have been regarded as equivalents of the Wealden deposits have undoubted Cretaceous affinities. Without attempting to decide this stratigraphical question in what is intended to be a local memoir, Mr. Strahan has laid stress on the classification which, though local, represents most naturally the relations of the rock-groups to each other in the South of England.

The exact limits of the Lower Greensand have been defined, and the striking discordance between the Lower and Upper Cretaceous rocks, so admirably displayed in this region, has been fully traced.

In describing the Tertiary series and the remarkable overlap which it presents, Mr. Strahan has been supplied with information by Mr. C. Reid, who has also furnished the notes on Calcareous Tufa given in chapter xiv.

One of the most important parts of Mr. Strahan's recent revision of the geology of the Purbeck district consisted in the recognition and detailed mapping of the disturbances and faults by which the formations have there been affected. He has shown that the movements occurred at several epochs, and that they included horizontal thrusts by which the Chalk has been ruptured and pushed over itself, in a manner not unlike that displayed by the thrust-planes of the north-western Highlands of Scotland.

Among the illustrations, five plates (1–5) have been reproduced from photographs of parts of the cliffs. The sheets of coast-sections (plates 9, 10, 11) have been prepared by Mr. Strahan, accompanied and assisted by Mr. Woodward.

To the Councils of the Geological Society and Geologists' Association, and to Dr. Henry Woodward we are indebted for the loan of *clichés* which appear in the text.

The fossils collected during the progress of the investigation have been identified by Messrs. Sharman and Newton, Palæontologists to the Survey, who have also corrected the lists of fossils and noted the synonymy. Mr. W. W. Watts has supplied notes on the microscopic structure of some of the Purbeck rocks.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
28, Jermyn Street, London,
9th February, 1898.

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PLATE VIII. Geological Map of the Isle of Purbeck and the Neighbourhood of Weymouth.
" IX. Sections along and transverse to the Coast from Jordan Hill, near Weymouth, to Lulworth Cove
" X. Sections along and transverse to the Coast from Lulworth Cove to Chapman's Pool.
" XI. Sections following the Coast from Chapman's Pool to the Foreland.

THE GEOLOGY
OF THE
ISLE OF PURBECK
AND
WEYMOUTH.

CHAPTER I.—INTRODUCTION.

Physical Features.

The district described in the following pages extends from the Foreland on the east to near Bridport on the west, and includes upwards of 60 miles of a coast which is hardly surpassed in interest in any other part of England. The Chalk downs which enclose the Hampshire Basin form the natural limit of the area in a northerly direction, as far as the neighbourhood of Bridport, where they turn northwards. The eastern part of the district includes the Isle of Purbeck, the boundaries of which are formed by the River Frome and an insignificant streamlet near Lulworth, known as Luckford Lake, though a more conspicuous physical feature exists in the "hog's back" of inclined Chalk which traverses the centre of the "Isle."

The line of downs in its more elevated parts attains the following heights above the sea:—Ballard Down 528 feet, Nine Barrow Down 655 feet, Knowle Hill 481 feet, and the Purbeck Hills 613 feet, terminating in Flower's Barrow 567 feet. Immediately to the south of this ridge, a low and heavily wooded belt marks the outcrop of the Lower Greensand and Wealden strata, which plunge beneath the Chalk at a high angle. Southwards, however, the dip gradually diminishes, and the rising ground which forms the south-eastern part of the "Isle" owes its shape to gently inclined or horizontal Purbeck shales and limestones, which overlie the Portland Stone of the precipitous cliffs between Durlston and St. Alban's Heads. In the south-western part of Purbeck, the Portlandian outcrop turns inland and forms the bold and continuous escarpment of which St. Alban's Head 354 feet, Emmit Hill 400 feet, Hounstout Cliff 501 feet, Swyre Head,* and Gad Cliff 482 feet, are the dominant points. Under this escarpment lies the hamlet of Kimmeridge, from which the clay lying next below the Portlandian takes its name.

In general structure, therefore, Purbeck resembles the Isle of Wight, its central anticline being moreover a direct continuation of the Brixton anticline of that island. Whereas, however, the upheaval towards the eastern end of the anticline sufficed to bring Wealden rocks only to the surface, here in Purbeck it possessed sufficient energy to raise the whole of the Purbeck and Portland formations and nearly all the Kimmeridge clay above the level of the sea, while at the same time the upheaval of the Chalk and superincumbent Tertiary beds was accompanied by faulting of remarkable character, as hereafter described.

The drainage of this part of Dorset follows the same laws as that of the Isle of Wight and the south-east of England, for the water-partings closely follow the axes of the post-Cretaceous anticline (Fig. 183). The southern boundary of the drainage-area of the Frome runs along the crest of the Purbeck anticline through the southern part of the Isle of Purbeck, the greater part of the drainage of which therefore makes its way northwards through the Chalk ridge. This apparently insurmountable barrier is passed by narrow defiles at Corfe Castle, and it is worthy of remark that the two brooks, Byle Brook from the east and Steeple Brook from the west, have each cut an independent valley through the ridge, though they run so near together as to leave a mere cone of chalk between, and unite a few yards further on in the Tertiary Basin. The origin of such features will be discussed in dealing with the physical geography of the district.

On the south side of the Purbeck anticline there is room for no more than a few short streamlets, which form almost the only relics of a river-system that has been swept away by the sea.

The Purbeck Hills are again breached at the west end of the Isle of Purbeck by the valley which opens on the bay of Arish Mell, but they continue westwards in Bindon Hill, 475 feet. A little further on the great Purbeck Fault runs into the sea, and the long ridge formed by the vertical Chalk merges itself in the broad Downs of Chaldon and Lulworth.

The Chalk of the Downs which extend from Winfrith to Black Down is faulted for the greater part of the distance against various members of the Oolitic series; in general this elevated tract presents a steep front to the south, and attains its greatest heights near the southern margin, while it declines gently to the north and north-east, in which direction the Chalk passes beneath the Tertiary rocks.

The Oolitic promontory on which Weymouth and Abbotsbury stand is diversified by the bold escarpment of Portland Beds which includes Corton Hill, Charlbury and other hills, and by the gentler undulations which mark the outcrops of the Corallian and Cornbrash. Nearly the whole promontory is drained by the River Wey and its branches.

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* The elevation of the highest point of this hill is not given on the six inch Ordnance Map. It is said to be the highest in Dorset, if an artificial mound on its summit be included.

The Island of Portland consists of an outlying mass of Portland Stone and Sand resting on Kimmeridge Clay and overlain by a sheet of Lower Purbeck strata. The dip being southerly, or rather to the east of south, the Portland Stone presents a bold escarpment to the north, approached by smooth slopes of Kimmeridge Clay.

A celebrated feature of this part of the coast is the great shingle-bank known as the Chesil Beach, which runs from Portland to beyond Bridport, a distance of 18 miles, and for 9 miles encloses a salt-water lagoon between itself and the shore.

Admirably as the features of this district illustrate the effects of the subaerial denudation that ensued upon the simultaneous folding and upheaval of the rocks, no less interesting is the form of coast due to the encroachment of the sea. Each formation as it abuts upon the shore gives rise to its own typical coast-scenery, the low foreshore and sand-dunes of the Tertiary area, the bare headlands of precipitous Chalk, the long curves of the bays in the Wealden, and the rocky prominences due to the Purbeck and Portland rock-beds, being all highly characteristic.

The Lulworth Coves moreover furnish an example of the dependence of coast-erosion upon geological structure that cannot easily be matched elsewhere. The strata being all highly inclined, the Portland and Purbeck rocks oppose to the advance of the sea a more or less wall-like barrier, which, however, has been broken through at intervals. The first effect of the barrier being penetrated is illustrated by Stair Hole, where a small gap and hole expose the softer sands and muds of the Upper Purbeck and Wealden to the rush of the waves and enable the débris to pass out to sea. The second stage is shown in Lulworth Cove, where the gap in the rock-barrier has attained a width of about 130 yards, and the hollow in the Wealden beds behind it a width of over 450 yards. The remarkable natural harbour thus formed is still of course growing in extent, but whereas it is enclosed to the east and west by soft Wealden strata, northwards it has reached the Chalk; with the result that it has already acquired a slightly oval form, and is proceeding towards the third stage which is exemplified in Worbarrow Bay. In this bay the rock-barrier has been swept away for a distance of a mile and a half, the Wealden beds of course having followed; northwards, however, the Chalk has proved a more stubborn obstacle and effectually checks encroachment for a distance of upwards of a mile. Stair Hole and Lulworth Cove are illustrated by the Frontispiece, which has been reproduced from a photograph by Mr. F. Mason Good.

TABLE OF STRATA.

The following Table shows the formations represented in this district in descending order :—

Blown Sand and Shingle Beaches		Recent.
Alluvium		
Tufa		Pleistocene
Raised Beach		
Angular Flint-gravel of the Downs (of indefinite age)		
Plateau Gravel		
Bagshot Beds		Eocene.
London Clay		
Reading Beds		
Upper Chalk and Chalk Rock		Upper Cretaceous.
Middle Chalk and Melbourn Rock		
Lower Chalk and Chloritic Marl		
Upper Greensand	inseparable over much of the area	
Gault		
Variegated Sands	Lower Greensand	Lower Cretaceous.
Atherfield Clay		
Wealden Beds		
Upper Purbeck with Marble-beds		Upper Oolitic Rocks.
Middle Purbeck with Building-stones		
Lower Purbeck with Tufas		
Portland Stone		
Portland Sand		
Kimmeridge Clay		
Corallian Beds		Middle Oolitic Rocks.
Oxford Clay		
Cornbrash		Lower Oolitic Rocks.
Forest Marble		
Fuller's Earth or Fullonian		

It is worthy of notice that the names of three such important groups as the Purbeck, Portland and Kimmeridge are taken from the area now under description. All three seem to have been introduced into geological literature by Thomas Webster in the years 1811–12*, though the term "Portland Lime" appears in Michell's table of strata in 1788.

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* Englefield's Isle of Wight.

CHAPTER II.—LOWER OOLITIC ROCKS

FULLER'S EARTH OR FULLONIAN.

Where best developed, this formation consists of clay with an interbedded limestone known as the Fuller's Earth Rock. In South Dorset, however, the "rock" has not been distinguished, and the sub-division consists of grey clays with a few thin rubbly limestones, the whole reaching probably a thickness of about 150 feet.

Among the most conspicuous features in the Fuller's Earth are the oyster-banks formed by the accumulation of the shells of *Ostrea acuminata* (Fig. 3). Several exposures of such banks occur in the shores of the Fleet south-west and south of Langton Herring,* a scarp south-west of the Coastguard Station disclosing more than 20 feet of oyster-shells. A similar rock is repeatedly exposed in the fields 400 to 600 yards north-east and east of the Station in a manner that suggests the presence of more than one oyster-bank. They are strictly local, as might be expected, and can be traced only a few yards. *Ostrea Sowerbyi* is associated with the *O. acuminata*, and *Serpula obliquestriata* occurs in blue clay above and below the oyster-beds.

Mr. H. B. Woodward in the Jurassic Memoir (Vol. IV., pp. 233, 234) remarks that "the lowest beds of the Fullonian, consisting of grey marly clay, are exposed in the cliffs between the mouth of the Bride or Bredy and Burton Bradstock. There they rest evenly on the Inferior Oolite, and are faulted at one point with a downthrow of 10 or 15 feet on the east; but the beds are not accessible, except in the tumbled masses that may occasionally be found on the foreshore. East of Burton Bradstock, at Cliff End, we again find the upper beds of the Fullonian, overlaid by Forest Marble. Near the junction, but belonging to the Fullonian, specimens of *Avicula costata (?)*, *Nucula Menkei*, *Eulima* and *Spinigera* may be obtained."

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* The occurrence of Fuller's Earth here was first noted by Damon, *Geol. of Weymouth*, 1860, p. 12.

FULLER'S EARTH FOSSILS.

FIG. 1.

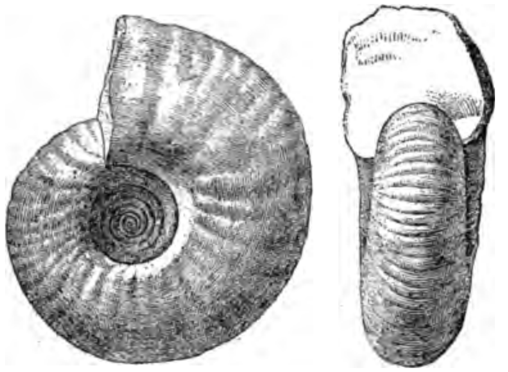

FIG. 3.

FIG. 4.

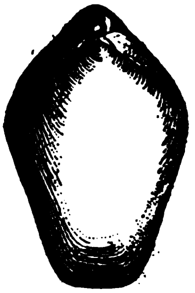

FIG. 2.

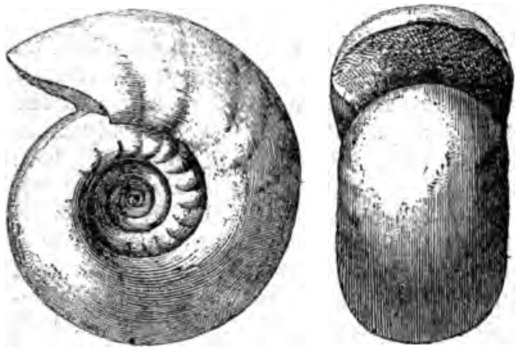

FIG. 5.

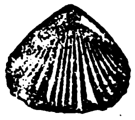

FIG. 1. Ammonites arbustigerus, d'Orb. ½.
„ 2. —— subcontractus, Mor. & Lyc. ½.
„ 3. Ostrea acuminata, Sow. Nat. size.
„ 4. Waldheimia ornithocephala, Sow. Nat. size.
„ 5. Rhynchonella varians, Schloth. 1½.

FOREST MARBLE.

This sub-division consists of grey clays with false-bedded oolitic and shelly ripple-marked limestones, irregularly interstratified but the limestones predominating towards the central part. "The lower clays near Bradford-on-Avon and other places contain at their base an abundance of fossils; and this division, though nowhere of great thickness, constitutes what is known as the Bradford Clay." (Jurassic Memoir, Vol. IV., p. 338.) *Apiocrinus*, the Bradford Clay encrinite, has been observed by the Rev. O. Fisher on the east side of the road to Portisham, north of Langton Herring, but it is undoubtedly scarce in Dorset.

In the absence of any marked division between the Fuller's Earth and the Forest Marble, a somewhat arbitrary dividing line had to be selected. A thin fossiliferous marl, crowded especially with *Rhynchonella Boueti* and *R. varians* (Fig. 5), was identified by

Mr. Woodward as the equivalent of the Bradford Clay of Wiltshire (*op. cit.*, p. 341), and, taking this as the base, he assigned about 80 or 90 feet of strata to the Forest Marble, in place of the 500 feet indicated by Damon.* There seem, however, to be about 130 or 140 feet of strata between this band as identified by Mr. Woodward at Herbury and the Cornbrash of Fleet Common.

The current-bedding of the limestones is a noticeable feature, and resembles the usual structure of sandstones rather than that of organically formed rocks. They are composed principally of the *débris* of shells, sometimes almost all oysters, but some bands contain *Terebratula* and *Rhynchonella* in such profusion that the soil abounds with well-preserved specimens. Lignite and tracks of crawling animals are common, and with the current-bedding point to a shallow-water origin for the deposit.

The Forest Marble, with the small inlier of the Fuller's Earth already described, occupies the central part of the Weymouth anticline. It has been dug in a number of places for walling-stone, for inferior roofing, and is still used for road-metal. The quarries show a somewhat monotonous repetition of grey clays alternating with slabs of oolite or shelly limestone, the latter forming small incontinuous scarps. On the western slope of Fleet Common a current-bedded and gritty oolite has been opened to a depth of 10 feet, but seems to die away within half a mile eastwards; south of Langton Herring, however, there are two or three parallel ranges of current-bedded shelly flags at nearly the same horizon, which have been much quarried for local purposes. Below these exposures we can trace the *Rhynchonella*-bed or basement clay of the Forest Marble, principally by the profusion of that shell in the soil, but partly also by the change to the grey and barren clay-soil and oyster-beds of the Fuller's Earth. "It is best exposed on the margin of the Fleet at a spot known as Herbyleigh (or Herbury), where it is overlaid by clays and shaly limestones, and it may also be seen on the borders of the West Fleet, south-west of Langton Herring." (Jurassic Memoir, Vol. IV., p. 341.)

At Abbotsbury the Forest Marble is nearly all overspread by landslips of Upper Greensand, but there is a small spring breaking out close to the fault west of Countess Coppice, from blue and white clay and white flags with *Rhynchonella* in profusion. Further west at about the same level that fossil is ploughed up in abundance, along a line moreover which runs parallel to the outcrop of a current-bedded limestone full of oysters. In the absence of more definite evidence the base of the Forest Marble is drawn along the line indicated by these *Rhynchonellæ*. The current-bedded limestone has been worked along Limekiln Hill and may be traced continuously from the point where it emerges from beneath the Upper Greensand of Abbotsbury Camp to the fault at Swyre, and again round the hill west of Swyre; its true dip is probably north and north-north-east at a gentle angle, but is difficult to detect from the prevalence of current-bedding planes dipping westwards. The same bed crosses Burton Common just above the Coastguard Station, while in the cliff below its position relatively to the *Rhynchonella*-bed can be determined.

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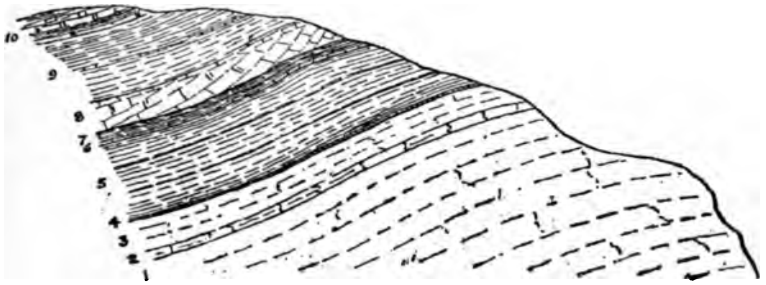
* *Geology of Weymouth*, 2nd Edition, p. 14.

FIG. 6.

Section at West Cliff, near Eype, Bridport (H. B. WOODWARD).



The divisions of the Forest Marble on the Dorset Coast are given by Mr. H. B. WOODWARD as follows (see Fig. 6):—

		FT.	IN
Cornbrash.			
Forest Marble	10. Flaggy blue limestone, showing ripple-marks, and clay or shales, with "race"; the limestone preponderating	10	0
	9. Clays with "race," shaly limestone, thin shelly limestone and thin leaves of sandy limestone, ferruginous in places; the clay preponderating	20	0
	8. False-bedded shell-limestones, sandy and oolitic in places, with irregular clay-seams, many ochreous galls, lignite; and with *Pecten*, *Ostrea*, and fragments of *Apiocrinus* ... ... 10 0 to	15	0
	7. Grey clay (not persistent)	3	0
	6. Hard white or grey marl, with thin seams of bluish shelly limestone	0	6
	5. Blue flaggy limestone-shales, and blue and yellow clays, with thin layers of calcareous grit, covered with curious markings ...	30	0
	4. Hard sandy marl stained reddish-brown; *Rhynchonella*-bed, with *Pecten vagans*, *Terebratula maxillata*, *Rhynchonella Morièrei*, *R. Boueti*, *Serpula*, &c.... ...	1	2
Fuller's Earth	3. Bluish-yellow marl, with impersistent band of hard fissile white marl	9	0
	2. Hard fissile white marl	2	9
	1. Grey marls, seen to thickness of	80	0

A similar sequence prevails south of Chilcombe, where the shelly limestone and calcareous sandstone in the upper and middle part of the formation have been quarried while the softer clays and Fuller's Earth form slopes below. The *Rhynchonella*-bed is recognisable on Bredy North Hill by the side of the road from Shipton

FOREST MARBLE FOSSILS.

FIG. 7.

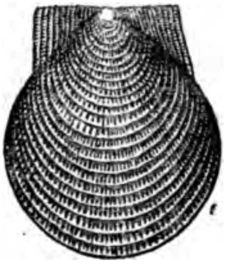


FIG. 8.

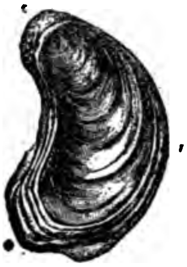


FIG. 9.

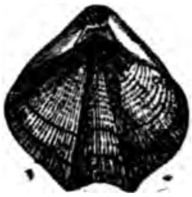


FIG. 10.

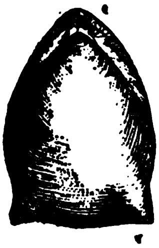


FIG. 11.

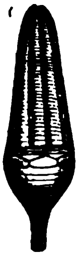


FIG. 7. Pecten annulatus, *Sow.* ⅓.
" 8. Ostrea Sowerbyi, *Lyc.* ⅔.
" 9. Terebratula coarctata, *Park.* × 2.
" 10. Waldheimia digona, *Sow.* × 2.
" 11. Apiocrinus Parkinsoni, *Schloth.* ⅓.

The following fossils were collected from the Forest Marble by Mr. WOODWARD :—

Radipole.

Ostrea lingulata, *Lyc. and Mor.*
Pecten lens, *Sow.*

West Fleet.

Rhynchonella concinna, *Sow.*
Terebratula maxillata, *Sow.*
Waldheimia digona, *Sow.*
Avicula costata, *Sow.*
Ostrea, sp.
Cyprina loweana, *Lyc. and Mor.*
Trigonia sculpta, *Lyc*

Herbyleigh.

Peronella pistilliformis, *Lamx.*
Acrosalenia spinosa, *Ag.*
Apiocrinus Parkinsoni, *Schloth.*
Cidaris bradfordensis, *Wright.*
Serpula intestinalis, *Phil.*
„ tricarinata, *Sow.*
Diastopora diluviana, *M. Edwards.*
Stomatopora dichotomoides, *Haime.*
Rhynchonella Boueti, *Dav.*
„ varians, *Schloth.*
Terebratula coarctata, *Park.*
„ intermedia, *Sow.*
„ maxillata, *Sow.*

Waldheimia digona, *Sow.*
„ obovata, *Sow.*
Avicula costata, *Sow.*
Gervillia.
Ostrea lingulata, *Lyc. and Mor.*
„ flabelloides (Marshi), *Sow.*
Pecten vagans, *Sow.*
Mytilus asper, *Sow.*
„ pectinatus, *Sow.*
Trigonia Moretoni, *Lyc.*
Pleurotomaria burtonensis, *Lyc.*
Turbo burtonensis, *Lyc.*
„ Phillipsi, *Lyc. and Mor.*

Langton Herring; west of the Signal Station.

Apiocrinus Parkinsoni, *Schloth.*
Serpula tricarinata, *Sow.*
Diastopora diluviana, *M. Edwards.*

Ostrea, sp.
Trigonia scarburgensis? *Lyc.*

Langton Herring; below the Signal Station.

Serpula.
Rhynchonella concinna? *Sow.* (top beds).
Rhynchonella Morièrei? *Dav.*

Terebratula maxillata, *Sow.* (top beds).
Waldheimia obovata, *Sow.*
Pecten.

Puncknowle.

Lima cardiiformis, *Lyc.*
„ duplicata, *Sow.*

Ostrea Sowerbyi, *Lyc.*

Bredy Hill.

Pentacrinus Milleri? *Aust.*
Rhynchonella Morièrei? *Dav.*
„ varians, *Schloth.*

Lima duplicata, *Sow.*
Pecten lens, *Sow.*

Burton Bradstock.

Serpula intestinalis, *Phil.*
„ tricarinata, *Sow.*

Rhynchonella Morièrei? *Dav.*
„ varians, *Schloth.*

Waldheimia obovata, *Sow.*
„ ornithocephala, *Sow.*

Lima cardiiformis, *Sow.*
„ duplicata, *Sow.* (North Hill.)
Ostrea, sp. (North Hill.)
Pecten, sp.
Cyprina loweana, *Lyc. & Mor.* (North Hill.)
Lucina burtonensis, *Lyc.*
Trigonia Moretoni, *Lyc.*

CORNBRASH.

This rock though thin extends continuously from Dorset to Yorkshire. It received this name in Wiltshire from the brashy or rubbly character of the limestone, but would be equally well described by it throughout the whole of the long outcrop. It consists of irregular bands of yellowish earthy limestone, sometimes blue-hearted, not oolitic, but frequently concretionary; and separated by layers of clay or shale. Lying between the comparatively soft Oxford Clay and Forest Marble, it usually makes a small but characteristic scarp. In thickness it ranges up to nearly 40 feet in Dorset.

CORNBRASH FOSSILS.

FIG. 12.

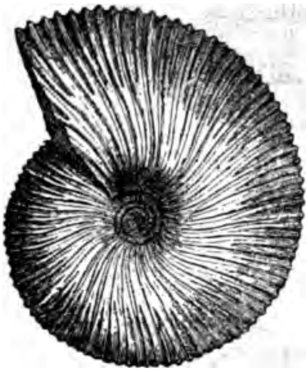


FIG. 13.

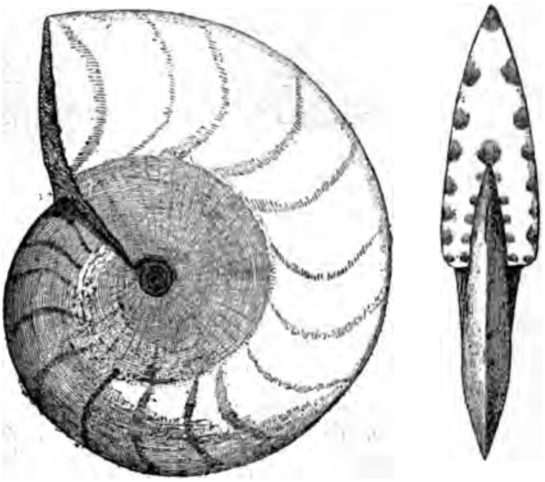


FIG. 14.

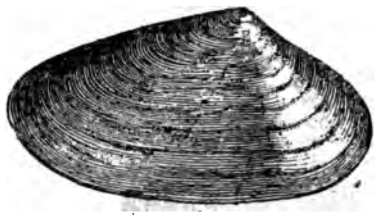


FIG. 15.

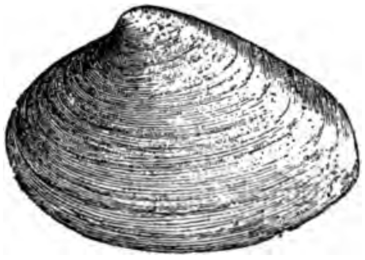


FIG. 12. Ammonites macrocephalus, *Schloth.* ½.
„ 13. Ammonites discus, *Sow.* ½.
„ 14. Myacites securiformis, *Phil.* ⅔.
„ 15. Gresslya peregrina, *Phil.* ⅔.

Though somewhat sharply divided from the Forest Marble, it is quite conformable to it; upwards it passes also into the Oxford Clay, and in fact contains many fossils in common with the Kellaways Rock in the lower part of that formation.

Cornbrash Fossils.

Fig. 16.

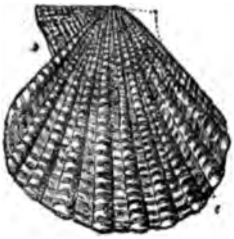


Fig. 17.

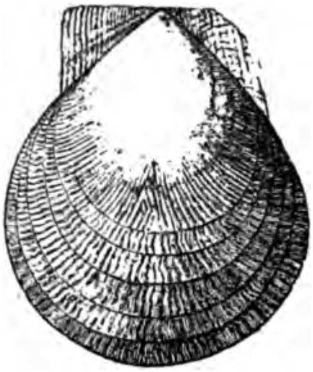


Fig. 18.

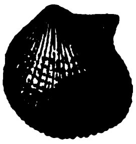


Fig. 19.

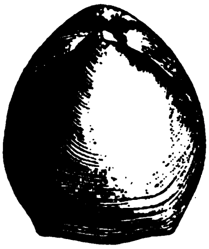


Fig. 20.

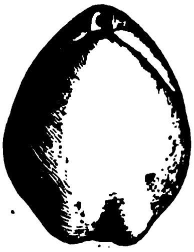


Fig. 21.

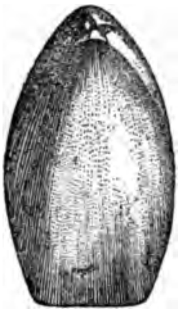


Fig. 22.

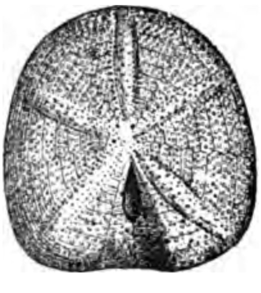


Fig. 16. Pecten vagans, *Sow.* nat. size.
„ 17. „ lens, *Sow.* nat. size.
„ 18. Avicula echinata, *Sow.* 1⅓.
„ 19. Waldheimia obovata, *Sow.* 1⅓.
„ 20. Terebratula intermedia, *Sow.* ⅔.
„ 21. Waldheimia lagenalis, *Schloth.* nat. size.
.. 22. Echinobrissus clunicularis, *Lhwyd.* nat. size.

The outcrop of the Cornbrash runs continuously round the Weymouth anticline, except where interrupted by some east and west faults, while outliers both of that rock and of the Oxford Clay are faulted in within the Forest Marble area. It reappears also at Swyre and Chilcombe, where again the outcrop with its characteristic features is several times repeated by similar dislocations.

One of the best sections occurs at the northern end of the Backwater, where the Cornbrash was formerly burnt for lime. The following details were noted by Mr. WOODWARD (Jurassic Memoir, Vol. IV. p. 436):—

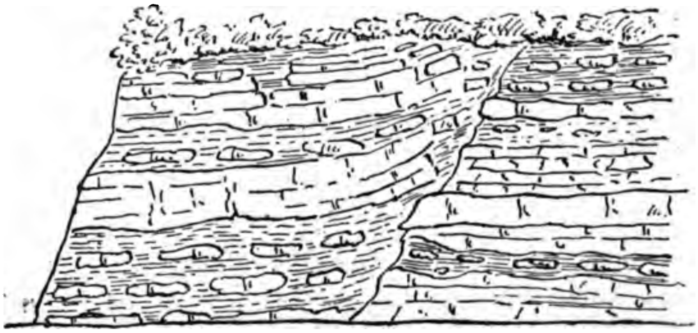
Radipole.

		FT.	IN.
Cornbrash -	Rubbly and sandy marls, the concretionary masses containing large oysters	1	6
	Flaggy, earthy, and nodular limestones, and irregular beds of sandy marl, with *Pholadomya* ...	9	6
	Bluish-grey limestones, merging downwards into shaly marls	3	0
	Hard bluish-grey earthy limestone, with *Rhynchonella*	1	0
	Rubbly and shelly limestones, with large *Pholadomya*, *Avicula echinata*, *Ostrea*, &c.	3	6
	Irregular shelly limestones	4	0

The large *Pholadomya* (*P. deltoidea*, Sow. = *P. bucardium*, Ag.) occurs abundantly in the lower bands of the Cornbrash in all the old quarries of this district. Carbonised drift-wood also is far from rare. The thickness of the Cornbrash here, according to Mr. WOODWARD, may be 30 feet. The accompanying sketch (Fig. 23), shows a small fault with a downthrow west of about 6 feet in the Cornbrash.

FIG. 23.

Section of Cornbrash at the north end of Radipole Lake, Weymouth. (H. B. Woodward).



There are several old quarries at East and West Chickerel, and on Fleet Common. Two faults here can be easily traced through the Cornbrash outcrop; the one running south-west tilts the strata up at 45° near Chickerel Church, and passes by East Fleet, where it throws the top of the Forest Marble against the base of the Oxford Clay; the other runs due north and south, and introduces a small inlier of Forest Marble on the coast. The same bed of limestone forms the shore at East Fleet and at the point west of this fault, thus indicating a horizontal displacement of the outcrops of 150 yards, or a vertical displacement of about 45 feet. The lower part of the Cornbrash here consists of:—

Near East Fleet.

		Ft.	In.
Cornbrash	Calcareous shale	1	0
	Hard limestone, the lower part in spheroidal concretionary masses	1	0
	Bullions of limestone in calcareous shale	2	0
	Hard limestone, seen to	2	0
Forest Marble	Shale and blue clay, crowded with dwarf oysters and *Serpulæ*		

The same junction half a mile further west is concealed by *débris*.

At Radipole the Cornbrash outcrop is faulted and difficult to trace. It runs from the Backwater to an exposure at Mount Pleasant, but is there shifted 800 yards westwards to Corfehill House, both north and south of which it can be detected in some old pits. It must also run by Nottington House, but is nowhere visible. West of the Wey, however, there are several quarries in the long faulted inlier of Buckland Ripers, chiefly in the lower part of the rock with the abundant *Pholadomya deltoidea*. The actual base is nowhere well shown, but in Langton Herring very fossiliferous nodular limestone is seen resting on shale with numerous oysters (Forest Marble).

The strip north of this consists, on the other hand, of the upper part of the Cornbrash only, passing naturally under the Oxford Clay, and in a pit on the east of the road from Rodden to Langton Herring Mr. Woodward saw:—

Near Rodden.

		Ft.	In.
Kellaways Beds.	Bluish mottled clay with *Waldheimia* and *Serpula*		
	Sandy and shelly shale		
Cornbrash	Greyish-brown earthy limestone in solid beds, exposed to a depth of	2	6

A few yards further south the fault is visible, the section running as below:—

		Ft.	In.
Cornbrash	Limestone, rubbly limestone, and shale	2	0
	Blue clay, shelly at base	4	0
	Limestone, seen to	2	0

Fault.

Forest Marble.—Blue clay with septaria

In the valley farther west the lower beds of the Cornbrash crop out, but there is a fuller exposure at Berry Knap on the shores of the Fleet, where about 38 feet of limestone and shale can be examined. The lowest limestone-band is upwards of 8 feet thick, but the others rarely exceed 2 feet in thickness, several of them consisting only of spheroidal concretionary masses arranged along a bedding plane. The same beds give rise to the projection known as Shipmoor Point.

The mode of occurrence of the Cornbrash at Puncknowle and Chilcombe is sufficiently explained by the map, and the sections resemble those already described. The junction with the Forest Marble is shown in some small faulted outliers intersected by the road from Litton Cheney to Abbotsbury, the large *Pholadomya* abounding here as elsewhere. The upper limit of the Cornbrash is not clearly exposed.

Cornbrash Fossils.

Collected by Mr. H. B. Woodward.

Localities.

1. Radipole.
2. Kiln, North of Chickerell
3. Crook Hill, south - west of Chickerell.
4. West Fleet.
5. Langton Herring, west of the Signal Station
6. Near Swyre Knoll.
7. Puncknowle.
8. North of North Hill, near Bridport Harbour.

Acrosalenia spinosa, *Ag.* 3, 8.
„ Wiltoni (?), *Wr.* 8.
Anabacia complanata, *Defr.* 6.
Echinobrissus clunicularis, *Lhwyd.* 3, 4, 5, 6, 8.
Pygurus Michelini *Cotteau.* 1, 4.
Serpula intestinalis, *Phil.* 3.
„ tricarinata, *Sow.* 1.
„ vagans, *Sow*, 6.
Rhynchonella concinna, *Sow.* 1, 3, 4, 7, 8.
„ varians, *Schloth.* 4.
Terebratula. 1, 2, 3, 6, 7.
„ maxillata (?). *Sow.* 8.
Waldheimia obovata, *Sow.* 1, 4, 7.
„ ornithocephala, *Sow.* 3, 4, 7, 8.
Avicula echinata, *Sow.* 1, 2, 3, 4, 6, 7, 8.
Lima, 8.
Ostrea costata, *Sow.* 8.
„ Sowerbyi, *Lyc.* 1, 2, 3, 7, 8.
Pecten demissus, *Phil.* 4.
„ fibrosus, *Sow.* 4.
„ vagans, *Sow.* 1, 2, 3, 6.
Ceromya concentrica, *Sow*, 3, 4, 6.
Goniomya v-scripta, *Sow.* 7.
Gresslya peregrina, *Phil.* 3, 4, 5, 6, 7.
Lucina. 2.
Modiola bipartita (?), *Sow.* 1.
Myacites calceiformis, *Phil.* 1, 7.
„ decurtatus, *Phil.* 1.
„ recurvus, *Phil.* 1.
„ securiformis, *Phil.* 5, 7.
Pholadomya deltoidea, *Sow.* Everywhere.
„ lyrata (?), *Sow.* 2, 7.
„ Phillipsii (?), *Mor.* 3, 4, 7.
Thracia ? 4.
Trigonia. 3.
Ammonites Bakeriæ ? *Sow.* 1.

CHAPTER III.—MIDDLE OOLITIC ROCKS.

OXFORD CLAY.

Two principal areas of this clay lie within the region under description, namely, that which runs from Abbotsbury to Broadway and Ham Cliff, and doubles back to the Fleet on the south side of the Weymouth anticline; and, secondly, the faulted tracts in the valley of the Bredy and at Chilcombe, the last-named being the most westerly exposure of the formation in this country. The clay is characteristically soft, and forms a featureless low country as in Lincolnshire, an approach to the conditions of the fenland being noticeable at Lodmoor, Abbotsbury, and along the Bredy. Its thickness has been estimated at about 500 feet, but there are no data for stating it with precision. Putting together observations made at various points, Mr. Woodward determines the following sequence (Jurassic Memoir, vol. v., p. 15):—

Zone of *Ammonites cordatus.*	4. Bluish-grey clay with small cement stones, and reddish coloured irregular septarian nodules ("kidney-stones"). Large specimens of *Gryphæa dilatata* are especially abundant, also *Ammonites cordatus*, *A. vertebralis*, *A. perarmatus*, *Modiola bipartita*, *Myacites recurvus*, &c.
Zone of *A. ornatus.*	3. Clays with small pyritic Ammonites: *A. athleta*, *A. hecticus*, *A. Lamberti*, *A. Mariæ*, and *Belemnites hastatus*, *Alaria trifida*, *Avicula inæquivalvis*, *Cardium Crawfordi*, *Nucula ornata*, *Thracia depressa*, *Pentacrinus*, &c. 2. Grey, greenish-grey and lilac rusty shales and paper-shales, with fragile fossils: *Ammonites Elizabethæ*, *Avicula ovalis*, *A. inæquivalvis*, small *Gryphæa*, &c.
Zone of *A. calloviensis* (Kellaways Beds).	1. Clay with occasional thin bands of flaggy calcareous sandstone, and large septaria: *Ostrea* (small). [*A. modiolaris*, *A. macrocephalus*, *A. Kœnigi*, &c., have been recorded from Weymouth].

LOWER OXFORDIAN FOSSILS.

FIG. 24.

FIG. 25.

FIG. 26.

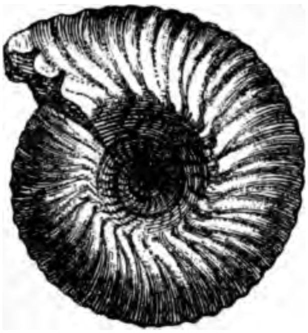


FIG. 27.

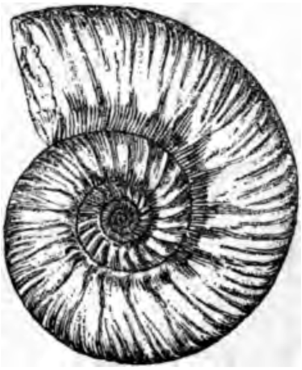


FIG. 28.

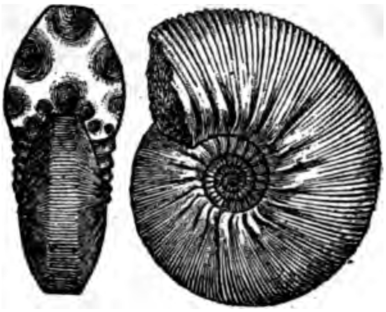


FIG. 30.

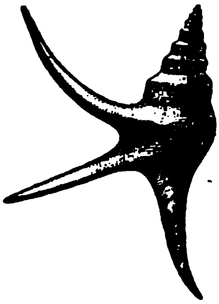


FIG. 29.

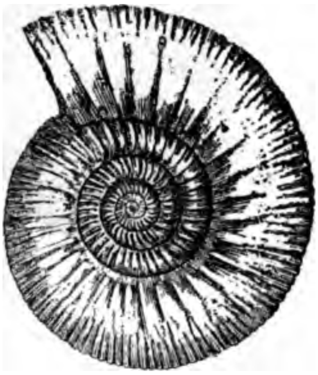


FIG. 31.

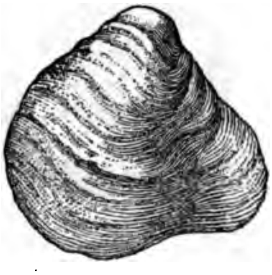


FIG. 24 and 25. Rhynchonella varians, *Schloth.* 1½.
„ 26. Ammonites modiolaris, *Lhwyd.* ⅔.
„ 27. „ Kœnigi, *Sow.* ⅔.
„ 28. „ calloviensis, *Sow.* ⅔.
„ 29. „ Bakeriæ, *d'Orb.* ⅓
„ 30. Alaria trifida, *Phil.*
„ 31. Gryphæa bilobata, *Sow.* ½.

MIDDLE OXFORDIAN FOSSILS.

FIG. 32.

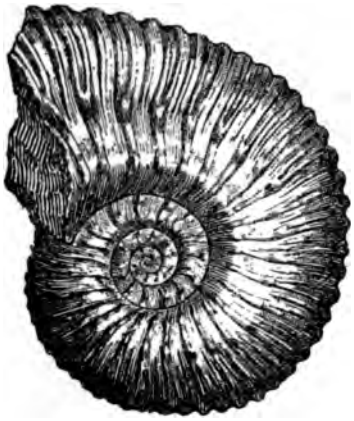


FIG. 33.

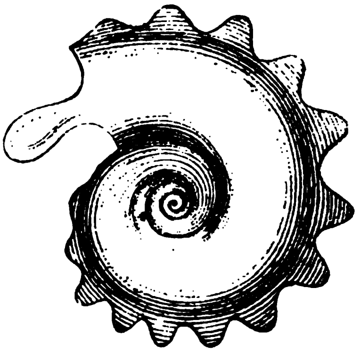


FIG. 34.

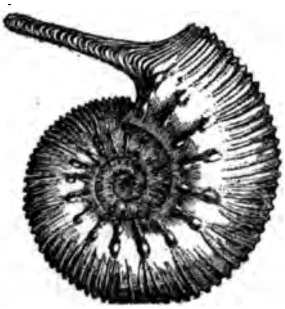


FIG. 35.

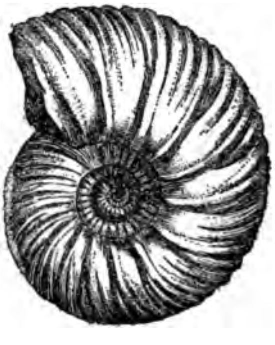


FIG. 32. Ammonites Duncani, *Sow.* 1½.
33. ,, crenatus, *Brug.* 2⅔.
34. ,, Jason, *Rein.* ½.
35. , Lamberti, *Sow.* ⅔.

UPPER OXFORDIAN FOSSILS.

FIG. 40.

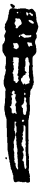


FIG. 36.

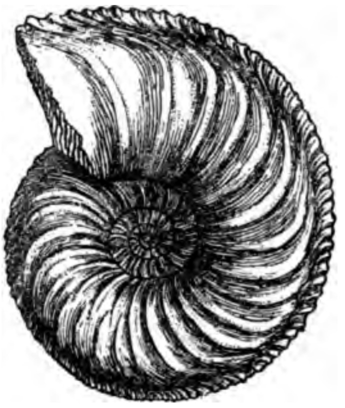


FIG. 37.

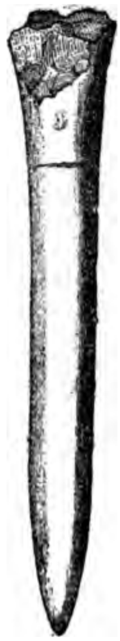


FIG. 38.

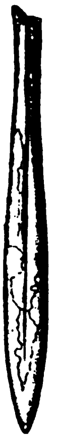


FIG. 39.

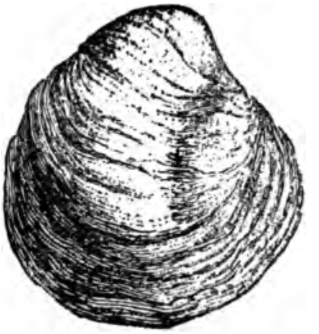


FIG. 36. Ammonites cordatus, *Sow.* ⅔.
„ 37. Belemnites Oweni, *Pratt.* ⅓.
„ 38. „ hastatus, *Blainv.* ¼.
„ 39. Gryphæa dilatata, *Sow.* ¼.
„ 40. Serpula vertebralis, *Sow.* Nat. size.

The easternmost exposure of the Oxford Clay occurs on the east side of Redcliff Point (Ham Cliff on the old edition of the one-inch map), where the clay rises from beneath the Corallian as described on p. 32. Its upper portion contains *Gryphæa dilatata* in abundance and *Modiola bipartita.* Midway between Redcliff and Short Lake (a small ravine west of Black Head) lower beds rise into view along the axis of an anticline which is doubtless continuous with that of Osmington Mills. They contain small pyritised ammonites, and are classed by Mr. Woodward with Group No. 3 of the table given above. A few yards south of the anticline the Redcliff fault intersects the cliff and throws down the upper zone of the Oxford clay again, together with a minute outlier of Nothe Grit (Plate ix.). The following fossils were obtained in Redcliff by Mr. Woodward :—

Cardium Crawfordi, *Leak.*
Gryphæa dilatata, *Sow.*
Nucula ornata, *Quenst.*
Thracia depressa, *Sow.*
Alaria trifida, *Phil.*
Ammonites Lamberti, *Sow.*
„ Mariæ, *d'Orb.*
Belemnites hastatus, *Blainv*

Furzy Cliff, the seaward face of Jordon Hill, consists of these same bluish-grey clays with few septaria or cement-stones. Under the Coastguard Station some slickensides with veins of calc-spar suggest a fault, but there is nothing to indicate any important displacement. " Reddish nodules with white, calcareous veins, known as 'kidney-stones,' occur on the beach at Redcliff and Jordon Hill ; they consist of hard cream-coloured septarian cement-stone with a shell of reddish-brown ironstone, and are derived from the Oxford Clay. Casts of *Modiola* and *Astarte* may be found in these nodules. Damon notes the presence of a Serpula-bed, with *Vermilia sulcata*, in the clay of Jordon or Furzy Cliff." (Jurassic Memoir, Vol v., p. 16.)

At Green Hill, in some low cliffs now much obscured, Damon obtained the following fossils from the upper part of the Oxford Clay :—

Ammonites athleta.
„ cordatus.
„ gowerianus.
„ Kœnigi.
„ Reginaldi.
„ vertebralis.
Belemnites hastatus.
„ Oweni.
Cerithium Damonis.
Gryphæa dilatata.
Nucula ornata.
Serpula vertebralis.
Vermilia sulcata.
Pentacrinus Fisheri.
Scales of Lepidotus.
Saurian bones.

The brick-pit at the Weymouth Brick, Tile, and Pottery Works, on the west shore of the Backwater, yielded to Mr. Woodward *Ammonites cordatus*, *A. perarmatus*, and *Gryphæa dilatata*, and were also assigned by him the upper part of the formation, though the position of the pit relatively to the Cornbrash and Corallian outcrops suggests that the beds are by no means the highest. On the margin of the Backwater, Mr. Woodward obtained *Ammonites Lamberti*, *A. Mariæ*, *Gryphæa dilatata*, &c., from clays with selenite and ferruginous cement-stones, and on the opposite side, in the railway, he observed fragile specimens of *Ammonites Elizabethæ*, *Avicula ovalis*, *Nucula ornata*, &c., in grey and green rusty shales.

The lower zones of the Oxford Clay form the low cliff of the Backwater south of Radipole Spa. They consist of shales with large septaria and a sandy layer, which has probably been a sandy limestone, and which, it is suggested by Mr. Woodward, may represent the Kellaways Rock.

Numerous fossils have been met with in deepening Weymouth Harbour, and have been recorded by Damon.* He refers also to the exceptionally beautiful markings of the septaria of Radipole.

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* *Geology of Weymouth*, 2nd ed., p. 27.

These concretions consist of a flattened, roughly spherical mass of the clay, bound *in situ* into a hard rock by carbonate of lime. The centre is generally occupied by an irregularly-shaped mass of yellow or rich-brown calcite, from which there radiate a series of veins of the same mineral, tapering away to a line as they approach the exterior. Many of them contain fossils, which, no doubt, were equally plentiful in the surrounding clay, but have perished. Damon describes one which contained "the trunk of a fossil tree, three feet in length, six inches in diameter, from the centre of which the spar radiates to the exterior of the trunk, which is surrounded by similar spar. From this outer coating there are other radiating septa passing into the indurated clay, or matrix." * A pavement of large septaria once existed in the shore of the Backwater, about 900 yards north of Weymouth Station, but has long since been destroyed.†

The following account of the shores of the Fleet and of the ground west of Weymouth is furnished by Mr. Woodward :—

" The Oxford Clay is exposed in low cliffs on the borders of the East Fleet, but the beds are not well shown throughout the tract, there being intervals where no section occurs.

" West of Wyke Regis the upper portion of the Oxford Clay is exposed below the Nothe Grits, and there *Ammonites cordatus*, *A. vertebralis*, *Modiola bipartita*, *Myacites recurvus*, and large specimens of *Gryphæa dilatata* are met with on the foreshore, together with ironstone and other nodules. To the north-west, many specimens of *G. dilatata* are met with in the promontory of Furzedown. Further on clays with ironstone-nodules occur east of Tidmoor Point; *Pentacrinus* likewise occurs, and a few large specimens of *G. dilatata*.

" At the western part of Tidmoor Point, clays with selenite are exposed, and numerous fossils are met with, including many small ferruginous Ammonites, *A. athleta*, *A. hecticus*, and *A. Lamberti*, *Belemnites hastatus*, *Cerithium*, *Avicula inæquivalvis*, *Gryphæa*, *Nucula ornata*, and *Pentacrinus*. These beds and portions of those below, belong to the zone of *Ammonites ornatus*. Rounding the point we find, on the northern side, blue clay weathering brown, with small species of *Gryphæa* and *Belemnites*. In the low cliff and on the shore in the centre of the bay, shales are exposed.

" East of the point south of East Fleet, shales with septaria are shown in the cliff, and at the point itself there is a platform of clayey shale with a few fossils; *Avicula inæquivalvis*, *Gryphæa*, and *Ostrea*. On the western side of the point the beds undulate a little, and here lilac rusty shales, and paper shales with selenite, fragile Ammonites, *Arca* and other small bivalves occur; also large septaria, one of which measured 4 feet across. Beyond, the beds are obscured by recent accumulations, and the junction with the Cornbrash is faulted; hence we have no information here with regard to the Kellaways Beds.

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* *Geology of Weymouth*, 2nd ed., p. 27.

† Buckland and De la Beche: *Trans. Geol. Soc.*, ser. 2, vol. iv., p. 28.

"At the brickyard south of West Chickerell, the lower Oxford Clay (zone of *Ammonites ornatus*), consisting of brownish-grey rusty shales, was exposed. *Avicula ovalis*, and many small fossils were to be found.

"On the northern side of the Weymouth anticline, between Broadway and the Swannery at Abbotsbury, we find a long vale of Oxford Clay, but no sections of interest, with the exception of one to the south of Rodden. There the Cornbrash and Kellaways Beds were shown in a pit on the east side of the road leading towards Langton Herring. The Kellaways Beds consisted of sandy and shelly shale, overlaid by bluish mottled clay, with *Waldheimia* and *Serpula*.*

"The Ridgeway cutting of the Great Western Railway, which crosses the great fault north of Upway, brought to light a mass of Oxford Clay and also beds or "blocks" of Cornbrash, the occurrence of which was first pointed out by C. H. Weston. (See Fig. 180.) The Rev. O. Fisher had indeed previously seen the section, in 1846, and he has remarked on the abundance of *Gryphæa dilatata*.† Weston obtained a number of fossils from the Oxford Clay, and these, which were named by Sowerby, included the following species ‡:—

Ammonites arduennensis.	Gryphæa dilatata.
„ Mariæ	Modiola bipartita.
„ perarmatus (catena)	Thracia depressa.

"It is curious that the Oxford Clay, judging by the above fossils, should be represented by its middle and upper portions, while the Cornbrash occurred in proximity." (Jurassic Memoir, vol. v., pp. 19, 20.) In addition, however, to the blocks of Cornbrash, the Oxford Clay contained what were thought by Mr. Fisher to be lumps of greensand, and there can be no doubt that the whole mass has been re-arranged. Its mode of occurrence is described in full on pp. 223-227, where also mention is made of a small inlier of Oxford Clay at Bincombe.

Three small outliers of Oxford Clay are faulted in with the Cornbrash along the Weymouth anticline near Langton Herring, but call for no special notice. At Long Bredy there are no clear sections of the Oxford Clay, but the outcrop which is suggested by the position of the Corallian Rocks is confirmed by the occurrence of *Gryphæa dilatata* on the fields. Similar evidence led to the mapping of the Oxford Clay tract near Chilcombe. On the south side of Hammerdon Hill an old brick-pit shows bluish-grey and purplish shales and clays with septaria, while *G. dilatata* occurs frequently in the soil. This tract of Oxford Clay seems to extend eastwards under the Upper Cretaceous Rocks as far, at least, as East Compton, where the following section was met with in a well:—

---

* See "Memoir on the Lower Oolitic Rocks of England," p. 436.

† Barnes, *Guide to Dorchester*, 1850 or 1851, pp. 30-32. This work has long been out of print, but Mr. Fisher's description is quoted in full on p. 225 of the present volume.

‡ *Quart. Journ. Geol. Soc.*, vol. iv., p. 250; vol. viii., p. 116.

Well at East Compton, sunk in 1855.

(Communicated to the Geological Survey by Mr. J. Hicks, Architect, Dorchester.)

		FT.	IN.
Upper Greensand.	Rock, sunk through to 40 feet Rock, bored through for 17 feet	57	0
	Greenish sand	10	0
	Rock	2	0
Upper Greensand—*continued.*	Yellowish sand	22	0
	Ironstone and shells	2	0
	Yellowish sand	19	0
	Rock, mundic (iron pyrites) and shells	3	0
	Blue clayey sand	18	0
	Rock	2	0
	Yellow sand	8	0
	Rock	2	0
	Yellow sand	23	0
	Rock	1	6
	Sand and water, which rose in pipes to the level of the boring	1	0
	Rock	1	6
Supposed Oxford Clay.	Blue clayey sand	4	0
	Rock with shell and metal	1	0
	Blue clayey sand	15	0
	Rock bed of metal	0	5
	Hard blue sand	32	7
	Dry sand Blue clayey sand, becoming more clayey	25	0
		250	0

CORALLIAN ROCKS.

This group of calcareous grits, oolitic limestones, and ironstones passes conformably both downwards into the Oxford and upwards into the Kimmeridge Clay. Though well developed both in Dorset and Yorkshire, it dwindles and loses its lithological characteristics in the intervening counties.

Our knowledge of these beds is due to the researches of Conybeare and Phillips,* Sedgwick,† Buckland and De la Beche, Damon, but more especially of Prof. J. F. Blake and Mr. W. H. Hudleston, who in 1877 gave a full description of the strata and their fossils throughout the country.‡ The general sequence previously recognised was threefold, namely, an upper and lower calcareous grit with an intermediate coralline oolite. Messrs. Blake and Hudleston, however, pointed out that the Weymouth Corallian strata present a sequence of eight sub-divisions of marked lithological and palæontological characters, which, although only locally recognisable, are of great interest. The following table shows the general sub-division, the local Dorset sub-division by Messrs. Blake and Hudleston, and the broad palæontological grouping of the Corallian:—

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* *Outlines of the Geology of England and Wales*, 1822.

† *Ann. Phil.*, vol. xxvii. (Ser. 2, vol. xi.), p. 346.

‡ *Quart. Journ. Geol. Soc.*, vol. xxxiii, p. 260 (1877). *Geol. Mag.*, 1878, p. 91.

		FT.	
Upper Calcareous Grit.	Upper Coral Rag and Abbotsbury Iron-ore ... ... Sandsfoot Grits	15 to 25	Zone of *Ammonites plicatilis.*
	Sandsfoot Clay	12 to 40	
Coralline Oolite.	Trigonia Beds	12 to 16	
	Osmington Oolite	45 to 60	
Lower Calcareous Grit.	Bencliff (or Bincleave) Grits	10 to 35	Zone of *Ammonites perarmatus.*
	Nothe Clay	30 to 40	
	Nothe Grits	20 to 35	

The total thickness of the Corallian series is estimated by Mr. Woodward to be constant at about 200 feet throughout the Weymouth district, in spite of the variations in the local subdivisions.

Both lithologically and palæontologically the upward and downward passage of the group is complete. In its upper part the Sandsfoot Clay not only resembles the Kimmeridge, but contains so markedly a Kimmeridgian fauna* that it was actually called by that name by Sedgwick. No less is the Nothe lithologically akin to the Oxford Clay, and, after enumerating its fossils, Messrs. Blake and Hudleston remark that "it is interesting to note that this list has, on the whole, more of an Oxfordian than a Corallian type, very few of the more peculiar forms of the latter appearing in it—a proof that in this district, at least, the fauna of the sands and grits makes its appearance rather on account of physical changes than on account of lapse of time."†

The origin of the name Corallian has been investigated by Mr. Woodward in the Jurassic Rocks of Britain, vol. v., pp. 70–71. The upper part of the Corallian group was referred to as Coral Rag by William Smith in 1815–16 in consequence of its great richness in corals in Wiltshire. In 1822 that term was applied to the whole of the group by Conybeare and Phillips‡ and remained in common use until recently, when the name Corallian, suggested by D'Orbigny in 1849,§ came into common use.

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* *Quart. Journ. Geol. Soc.*, vol. xxxiii, p. 270 (1877).

† *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 264.

‡ *Outlines of the Geology of England and Wales*, 1822, p. 185.

§ The name Corallian was taken from the *Calcaire corallien* of Thurmann, D'Orbigny, *Pal. Française, Terrains Jurassiques*, tome 1, p. 609.

Corallian Cephalopods and Gasteropods.

Fig. 41.

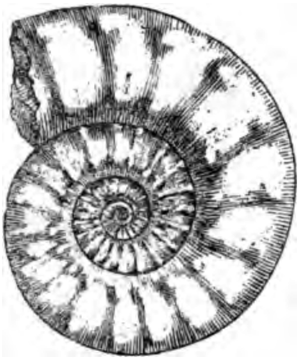


Fig. 42.

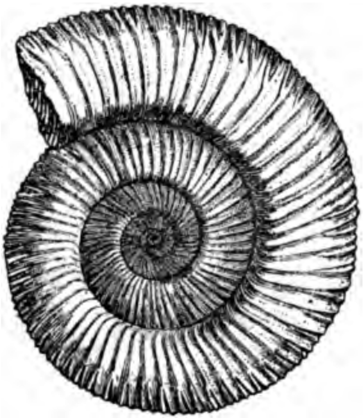


Fig. 46.

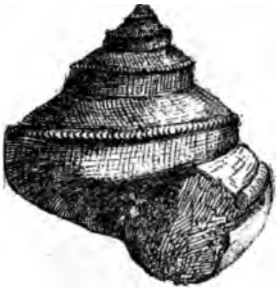


Fig. 44.

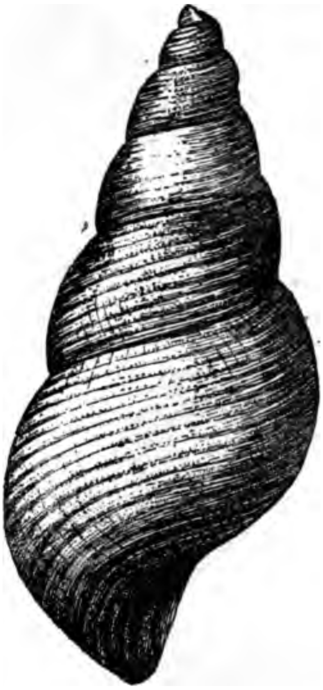


Fig. 43.

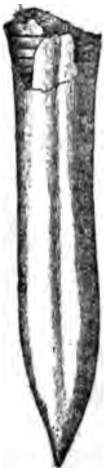


Fig. 45.

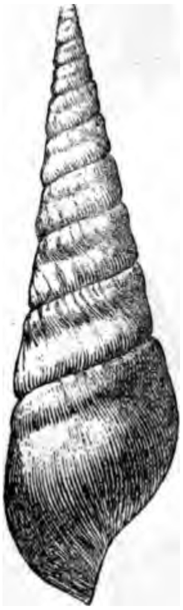


Fig 41. Ammonites perarmatus, *Sow.*, ¼.
„ 42. —— plicatilis, *Sow.*, ⅙.
„ 43. Belemnites abbreviatus, *Mill.*, ⅓.
„ 44. Bourguetia (“Phasianella”) striata, *Sow.*, ⅔.
„ 45. Pseudomelania (Chemnitzia) heddingtonensis, *Sow.*, ⅔.
„ 46. Pleurotomaria reticulata, *Sow.*, ⅔.

CORALLIAN LAMELLIBRANCHS AND BRACHIOPOD.

FIG. 47.

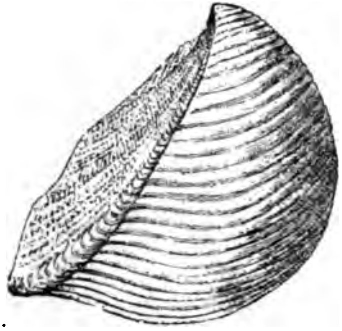


FIG. 48.

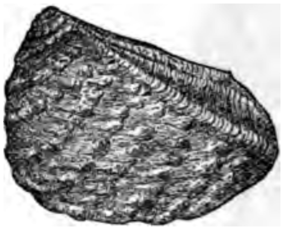


FIG. 49.

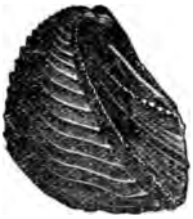


FIG. 50.

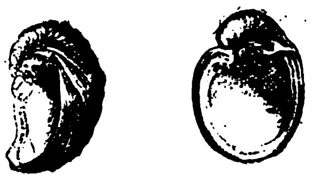


FIG. 52.

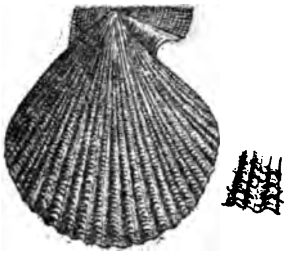


FIG. 51.

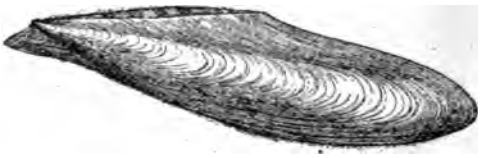


FIG. 53.

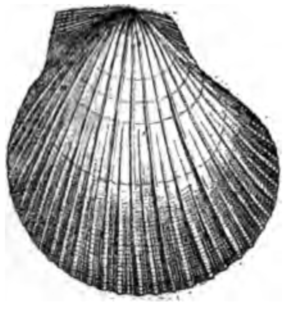


FIG. 55.

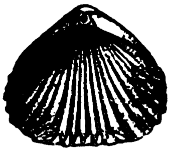


FIG. 54.

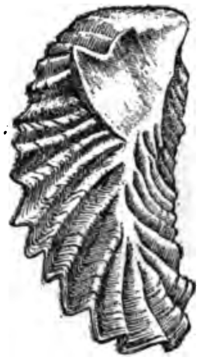


FIG. 47. Trigonia Meriani, *Ag.*, ½.
„ 48. —— clavellata, *Sow.*, ½.
„ 49. —— monilifera, *Ag.*, ⅔.
„ 50. Exogyra nana, *Sow.*, Nat. size.
„ 51. Gervillia aviculoides, *Sow.*, ½.

FIG. 52. Pecten articulatus, *Schloth.* Nat. size.
„ 53. Hinnites tumidus, *Ziet.*, ⅔.
„ 54. Ostrea gregaria, *Sow.*, Nat. size.
„ 55. Rhynchonella varians, *var.* Thurmanni, *Voltz*, ⅔.

CORALLIAN ECHINOIDS.

FIG. 56.

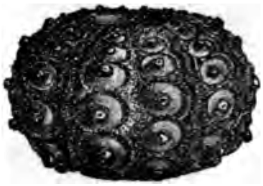


FIG. 57.

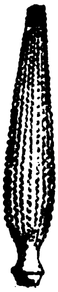


FIG. 58.

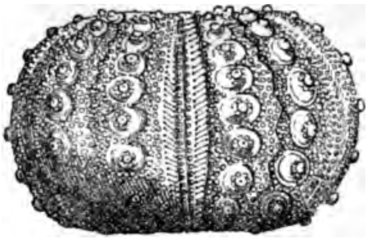


FIG. 59.

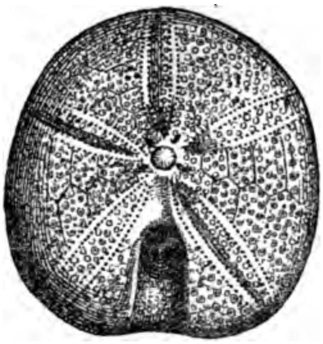


FIG. 60.

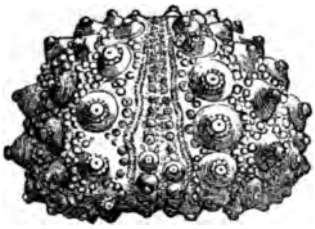


FIG. 56. Cidaris florigemma, *Phil.*, ½.
„ 57. —— —— spine, ⅔.
„ 58. —— Smithi, *Wright*, ⅔.
„ 59. Echinobrissus scutatus, *Lam.*
„ 60. Hemicidaris intermedia, *Flem.*

CORALLIAN CORALS.

FIG. 61.

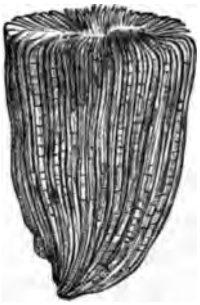


FIG. 62.

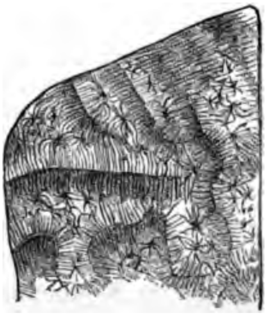


Fig. 63.

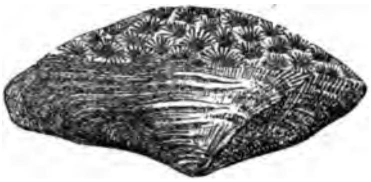


Fig. 64.

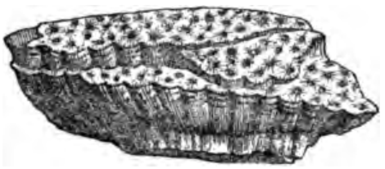


Fig. 65.

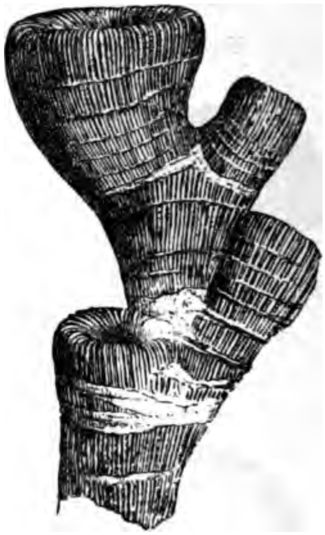


Fig. 61. Montlivaltia dispar, *Phil.*
„ 62. Comoseris irradians, *M. Edw.*
„ 63. Isastræa explanata, *Goldf.*, ⅔.
„ 64. Thamnastræa arachnoides, *Park.*, ½.
„ 65. Thecosmilia annularis, *Flem.*, ⅔.

A prominent characteristic of the Corallian is the oolitic structure of many of the limestones, conspicuous among which is the beautiful white rock of the Osmington Oolite. Such deposits are found at the present day in association with coral-reefs, and Mr. Woodward remarks that "it is interesting to find that, as is the case with the Inferior Oolite and the Great Oolite, there are bands of coral growth associated with the more oolitic beds in the Corallian formation." Microscopic sections of the rocks have been examined by Mr. J. J. H. Teall, who reports as follows:—

"In the Osmington Oolite the grains shew concentric and radiate structure with *Girvanella*-structure (?) in the nuclei of one or two grains. Quartz grains act as nuclei in several instances, and there are small black grains scattered through some of the oolitic grains. Fragments of shell also occur, and the matrix is of clear crystalline calcite and calcareous mud.

The top bed of Coral Rag at Ringstead Bay, an iron-shot earthy limestone, shewed brown grains of ferruginous oolite and angular fragments of quartz in a fine-grained calcareous matrix." (Jurassic Memoir, vol. v., pp. 72, 73.)

Ringstead Bay and Redcliff (Plate IX.)

The Corallian Rocks form the foreshore for some distance along this bay. In proceeding westwards from White Nothe we reach the lower beds of the Kimmeridge Clay in a ravine 700 yards east of the Methodist Chapel, and 200 yards further on find the "Coral Bed" or uppermost zone of the Corallian clearly exposed at the top of the beach. Thence it can be traced with the clays containing *Ostrea deltoidea* above it for more than half-a-mile. This band is the "Kimmeridge Grit" of Damon, and the "Upper Coral Rag" of Messrs. Blake and Hudleston; though less than a foot thick it is richly fossiliferous and contains in abundance the corals *Thamnastræa concinna* and *Thecosmilia*, "with an assemblage of highly characteristic fossils, *Pecten vimineus*, *Lima rigida*, *L. pectiniformis*, species of *Cidaris florigemma*, &c., in a hard marly grit" (Blake and Hudleston, *op. cit.*, p. 272). A few yards out from the shore the Trigonia Grits, in two beds with 5½ feet of clay between, form the Ringstead Ledge, which is bare at low water. The Coral Bed can be identified again, as an ironstone, in the upper part of the cliff near the Cabin, while some red grit, belonging to the Sandsfoot sub-division, crops out in the foreshore. Further on these grits form the dip-slope on which Upton House stands, and are overlain, in the highest part of the hill only, by a thin sheet of the Coral Bed.

The following fossils collected by Mr. Woodward in the Coral Bed of Ringstead Bay may be added to those mentioned above:—

Thecosmilia annularis, *Flem.* (Fig. 65)
Rhynchonella inconstans.
Serpula tricarinata, *Sow.*
„ variabilis, *Sow.*
Exogyra nana, *Sow.*
Hinnites.
Lima rigida, *Sow.*
„ pectiniformis, *Schloth.*
Ostrea gregaria, *Sow.* (Fig. 54)
Pecten articulatus, *Schloth.* (Fig. 52)
Astarte ovata, *W. Smith.*
Modiola bipartita, *Sow.*
Modiola imbricata, *Sow.*
Myacites recurvus, *Phil.*
Pholadomya paucicosta *Röm.*
Myoconcha.
Trigonia.
Unicardium.
Littorina pulcherrima, *Dollf.*
Natica.
Phasianella striata, *Sow.*
Pleurotomaria reticulata, *Sow.*
Ammonites mutabilis, *Sow.*
„ pseudomutabilis, *De Lor.*

Westwards along the foreshore the harder bands in the Corallian form a succession of reefs, each of which curves round and presents a convexity towards the east, in consequence of an anticline which runs parallel to the cliff and a few yards from it. Thus the Trigonia Grits form Perry Ledge, and the Osmington Oolite, with 2½ feet of shelly limestone above, Bran Ledge; the Bencliff Grits probably crop out in Frenchman's Ledge and other not easily accessible reefs, while the Nothe Grits give rise to Hannah's Ledge.

The whole sequence (except the base of the Nothe Grit) as exposed in this cliff between the Cabin and Osmington Mills is given in the following table by Mr. Woodward (Jurassic Memoir, vol. v., p. 85):—

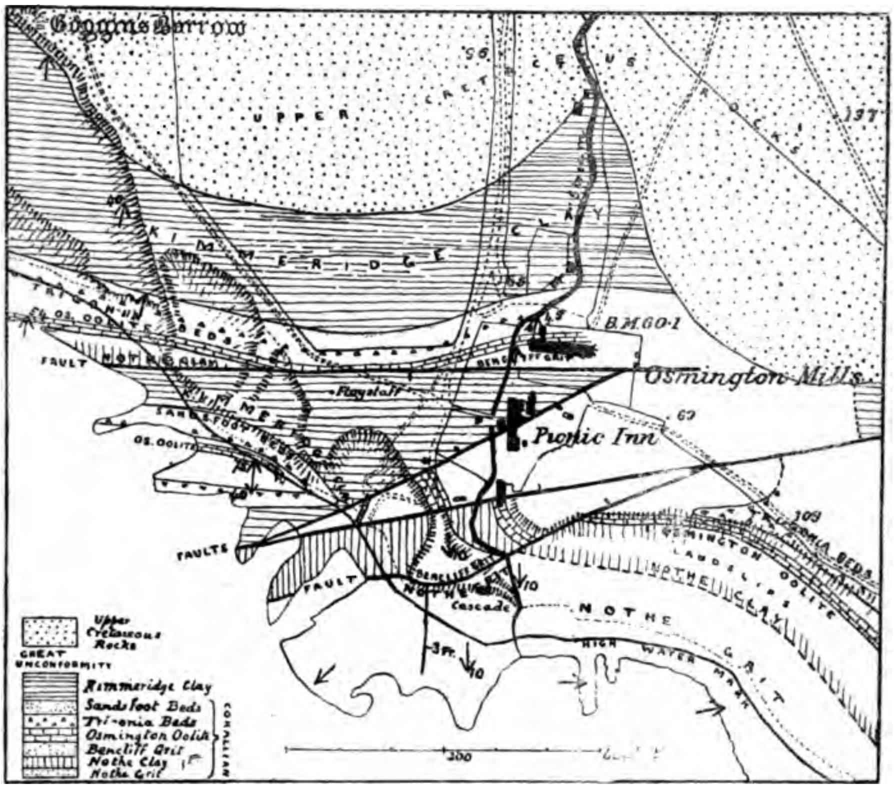
		FT.	IN.
Kimmeridge Clay	Clay with layers of *Ostrea deltoidea*, *Rhynchonella inconstans*, *Serpula intestinalis*, &c.		
	Band of shelly limestone with *Exogyra nana*.		
	Clay - - - - -	2	0

		FT.	IN.
Upper Coral Rag and Sandsfoot Grits.	Grey earthy limestone. Fossil-bed -	0	6
	Ferruginous beds: clay with bands of nodular ironstone and gritty calcareous bands. *Ostrea deltoidea* - -	14	0
	Red grits (one or two beds) and grey, gritty, and sandy beds - 2 0 to	4	0
Sandsfoot Clay -	Clays with *O. deltoidea* - 10 0 to	12	0
Trigonia Beds -	Grey, and more or less iron-stained and oolitic limestones, with abundant fucoidal markings; divided in places by 4 ft. of yellowish-grey oolitic marl, and thin clay bands; with *Ammonites*, *Ostrea solitaria*, *Pecten fibrosus*, *Perna mytiloides*, *Pholadomya æqualis*, *Trigonia Meriani*, *T. clavellata*, &c. -	15	9
Osmington Oolite	Rubbly and nodular limestones, alternating with bands of oolite (more or less shelly), oolitic marl, and occasional pisolite, the most conspicuous band of pisolite being about 6 feet from the base. *Pecten*, *Chemnitzia*, *Nerinæa*, *Ostrea*, *Trigonia*, *Echinobrissus dimidiatus*, and plant-stem. The basement-bed is a calcareous and oolitic grit with tubiform and fucoidal markings - - - - about	60	0
Bencliff Grits -	Brown false-bedded sands, with large concretionary masses of calcareous sandstone, or "Doggers," and flaggy beds, showing ripple-marks, with laminated clay and sand, and seams of carbonaceous clay: seen to a thickness of - - - - - - -	11	6
Nothe Clay	Clays [the full thickness of these clays could not here be estimated, owing to the junction with the overlying Bencliff Grits being hidden by slips; and the beds are at one point faulted].		
Nothe Grits	Greyish calcareous grits, shales, marly clays with bands of nodular calcareous sandstone: *Gryphæa dilatata* abundant, *Ostrea*, *Serpula*, &c. Seen to depth of - - - - - - -	12	0

On the shore east of Osmington Mills, as also under Redcliff (p. 34), there lie many huge spheroidal or oval masses of calcareous sandstone from 3 to 6 feet or more in diameter. They consist of a false-bedded sandstone and have fallen from the Bencliff Grit. Such concretionary masses, or "doggers" are not uncommon in slightly calcareous sandstones, their formation depending apparently upon the presence of a small quantity but not a superabundance of lime in the rock, and upon the existence of impervious strata above or below to prevent the complete removal of the lime by the water circulating in the sandstone.

At Osmington Mills a belt of faults in association with a sharp anticline causes great complication. The fact that the faults and folds are nearly parallel to the coast making it impossible to render the structure clear on the coast-section given in Plate IX., a portion of the six-inch map has been enlarged to form Fig. 66.

FIG. 66.—*Map showing faulted anticline at Osmington Mills.*



East of the Cascade an undercliff overlooked by low crags of Osmington Oolite marks the position of the Nothe Clay, the clay itself with *Gryphæa dilatata* being visible 150 yards east of the Cascade and again beyond Hannah's Ledge. The Cascade shows the passage-beds from these clays into the Nothe Grits, the rocks exposed consisting of blue clayey sand passing down into a clayey sandstone with *Gryphæa dilatata*, which forms the foreshore.

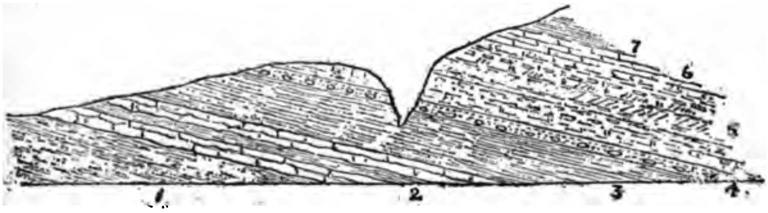
About 20 or 30 yards above the Cascade the first fault crosses the stream and throws down the Nothe Clay and overlying Bencliff Grit against the Nothe Grit, as can be seen in the face of the cliff on the south and west sides of the promontory. A few yards further north a second parallel fault throws down the Bencliff Grit still lower and introduces a little strip of Osmington Oolite, which can be identified 50 yards south-west of the Inn. Lastly a third down-throw north running from the landing stage under the Inn throws the Corallian down to sea-level and brings in the Kimmeridge Clay. Crossing the Kimmeridge Clay for about a hundred yards we find a fourth large fault, parallel to the others, but with a down-throw south, throwing it against Nothe Clay on the shore and against Bencliff Grit in the stream by the Coastguard Station. The faults therefore may be described as letting down a wedge of Kimmeridge Clay into the Corallian outcrop, the displacement on the southern side being accomplished in three steps.

The wedge thus introduced is bent up into a very sharp anticline, which is admirably dissected in the foreshore west of the landing stage. The Coral Bed can be followed along the lower part of the cliff of Kimmeridge Clay to the landing stage where it is cut off by one of the step-faults, but the Trigonia Beds and Osmington Oolite dipping at 70° northwards in the northern limb of the anticline can be traced inwards to the foot of the cliff, whence they double sharply back westwards again with a southerly dip of 40° in the southern limb of the same fold. It is this anticline which causes the steep northerly dip of the Oolitic rocks of Black Head, and thus gives rise to the straight railway-like reefs of Corallian strata at the foot of that cliff. It can be identified also in Redcliff Point, but much diminished in intensity. The fact that the Upper Cretaceous rocks rest horizontally upon these upturned Oolites prove that the movements belong to the earliest of the several sets of disturbances described elsewhere (p. 228).

Among the reefs at the foot of Black Head we recognise the Trigonia Beds enclosing a long lagoon, the Osmington Oolite just outside them, and the *Ostrea deltoidea*-beds of the Kimmeridge Clay with the Coral Bed in the foot of the cliff. Further west the Nothe Grits form a long straight reef which strikes the shore near Short Lake, a small ravine two-thirds of a mile east of Redcliff Point. The top of the Oxford Clay rises from below the beach 150 yards west of the ravine, and the ravine itself shows Nothe Clay, Bencliff Grits and Osmington Oolite, while the higher beds are equally well exposed close by. The section was measured by Mr. Woodward with the following result (Jurassic Memoir, vol. v., pp. 86, 87):—

FIG. 67.

Section of the Cliff west of Black Head, near Osmington (H. B. Woodward)



4. Bencliff Grits. } Lower
3. Nothe Clay. } Corallian.
2. Nothe Grits. }
1. Oxford Clay.

7. Sandsfoot Clay. } Upper.
6. Trigonia Beds. } Corallian.
5. Osmington Oolite. }

		Ft.	In.
Kimmeridge Clay.	Blue clays.		
	Band of gritty limestone with *Exogyra nana*, *Serpula*, &c.		
	Clays with *Ostrea deltoidea*, *Rhynchonella inconstans*, &c.		
Upper Coral Rag.	Grey earthy and ironshot limestone, irregular and nodular; fossil-bed ...	3	6
Sandsfoot Grits.	Clays with ironstone nodules, gritty calcareous bands, and cement stones: *Ostrea deltoidea*, *Rhynchonella*; thickness variable from about 9ft. to ...	12	0
	Red, brown, and greenish-grey oolitic and calcareous and ferruginous sandstones, with quartz grains: *Ostrea deltoidea* (in layers), *Belemnites*, *Serpula*, &c. ...	7	6
Sandsfoot Clay	Bluish-grey clay with layers of *Ostrea deltoidea*	11	0
	Sandy and ferruginous clays, with sandy ironshot nodules ...	4	0
	Bluish-grey marly clay with pale earthy cement stones: *Ostrea deltoidea* ...	10	0
Trigonia Beds	Red, grey, and purplish-coloured calcareous gritty and ferruginous rocks, in irregular beds, shelly and sparry, and more or less oolitic, with bands of oolitic marl and clay: *Ammonites plicatilis*, *Nerinæa*, *Gervillia*, *Trigonia clavellata*, and Corals ...	14	0
Osmington Oolite.	Irregular bluish nodular oolitic limestones and marls, with *Chemnitzia*-bed in upper part, that forms a prominent whitish ridge along the foreshore. *Ammonites*, *Pleurotomaria* ...	10	0
	Shelly oolite and oolitic marly clays ...	5	6
	Clays and nodular earthy limestones (thicker in places) ...	6	0
	Oolite, shelly, ferruginous, and pisolitic (at base): *Ostrea*, plant-remains, and tubiform markings	6	6
	Bluish-grey oolitic marl, with impersistent band of pale earthy limestone ...	2	0
	False-bedded oolite with shelly layers, *Pecten*, and vertical tubiform markings at base ...	9	0
	Oolitic marly bed ...	0	10
	False-bedded shelly oolite, with tubiform markings	1	0
	Rubbly earthy limestones and marls, oolitic in places ...	10	0
	Grey iron-shot oolite and pisolite ...	2	0
	Marly oolitic clay, with irregular band of sandy and shelly oolite ...	6	0
Bencliff Grits.	Laminated sands and clays, and indurated yellow sands, with doggers of hard blue calcareous sandstone (some 6 feet in diameter) ...	10	0
	Flaggy grits ...		
Nothe Clay.	Bluish sandy clays: *Ostrea*, *Pleurotomaria*, and *Serpula*, near base ...	40	0
Nothe Grits.	Alternations of irregular and rubbly-looking calcareous grits (much iron-stained), and bluish marly clay ...	12	0
	Bluish-grey marly clay ...	8	0
	Bluish and yellowish-grey, slightly calcareous sandstones, with impure cement-stone nodules; fucoidal markings on the surfaces of the beds, the top layer a massive shelly bed, *Gryphæa dilatata*, *Pleurotomaria*, &c. ...	15	0
Oxford Clay.	Bluish-grey clay, with calcareous nodules near top.		

The total thickness of the Corallian Beds here is estimated by Mr. Woodward to be about 203 feet.

Redcliff Point (Ham Cliff on the old one-inch map) is crossed by an east and west fault, which throws Osmington Oolite down on the north on a level with a small knob of Nothe Grit on the south, and which doubtless corresponds to the step-faults of Osmington Mills, for like them it runs a short distance south of the steep northern limb of the anticline. Westward of the point a fine cliff exposes nearly horizontal Corallian rocks including the oolite at the top, and the junction with the Oxford Clay at the bottom, two or three feet above the beach. The following section is furnished by Mr. Woodward:—

	Redcliff.	FT.	IN
Osmington Oolite.	Pale rubbly slightly oolitic limestone ... ... Hard beds of flaggy oolite ... ... Shaly and marly beds, 4 to 6 ft., but thickening westwards ... ... Flaggy and rubbly oolite, with ripple-marks ... Rubbly oolite passing westwards into harder beds; *Chemnitzia* in fallen blocks	16	0
	Bluish clay, 6 in.		
	Pale and dark sandy clays, more sandy at top; thin layers of ironstone and bands of irregular white earthy concretionary limestones or marls. Base obscured by landslips	15	0
Bencliff Grits...	Ferruginous grits. Hard flaggy and laminated calcareous sandstone with vegetable impressions; 5 ft. Blue clays with rubbly and sandy beds and doggers in lower part		
Nothe Clay ...	Blue clays, with ferruginous layers in the lower part ... ... Clays with two or three ferruginous sandy limestones; *Belemnites*, *Pecten*, &c. 4 ft. ... Soft grey calcareous sandstone, 1½ ft. ... ... Bluish clay with indurated calcareous bands, *Ostrea*, *Pecten*, &c. 12 ft.	about 25	0
Nothe Grits ...	Hard brown calcareous grit, forming projections, and lying in large masses on the shore. 3 to 3½ ft. ... ... Softer sandy beds, concretionary; bivalves, Ammonites ... ... Sandy clays with hard beds, nodules and doggers of calcareous grit; *Lima rigida*, *Chemnitzia heddingtonensis* (?), *Homomya* (?), *Myacites securiformis*. 4 ft. ... ... Calcareous grit and bluish shaly grits weathering brown, with fucoidal markings and many fossils; *Gryphaea dilatata*, *Ostrea gregaria*, *Pecten fibrosus*, &c. 6 or 7 ft.	about 40	0
Oxford Clay	Sandy clays with hard limestone nodules: passing down into indurated calcareous clay. 4 ft. ... ... Bluish sandy clay with 2 ins. of earthy limestone; on the shore many red kidney-stones	seen to 6	0

The top of the Nothe Grits, the Nothe Clay and the Bencliff Grit are much obscured by landslips. The last-named division has yielded some great flattened circular or oval doggers, which lie upon the shore. They consist of hardened greenish-yellow calcareous sandstone, finely current-bedded, and sometimes exceed 6 feet in diameter. The top of the Oxford Clay quickly sinks below the beach, but rises into view again on the east side of the River Jordon.

Broadway.

At Redcliff the Corallian outcrop leaves the shore and runs by Broadway to Abbotsbury, on the north side of the broad Weymouth anticline. A few sections only occur until we get near Broadway, but there the Osmington Oolite has been quarried along most of its outcrop for walling-stone and lime-burning, while the Nothe Grits form a recognisable escarpment, though, as noticed by Messrs. Blake and Hudleston, they are tending to thin westwards. The junction with the Oxford Clay is exposed in the railway-cutting 100 yards south of Upway Junction, and the Trigonia Beds and Osmington Oolite are well exhibited in the cutting east of Broadway Station, referred to by Mr. Woodward in the Jurassic Memoir, vol. v., p. 92.*

Cutting east of Broadway Station.

	Ft.
Flint gravel	1 to 2
Clay and oolitic limestone (Sandsfoot Clay in part) ...	20
Calcareous and shelly grit with a band full of *Trigonia* (Trigonia Beds)	12
Oolitic limestone and clay full of ooliths (Osmington Oolite) seen to	6

Mr. Woodward records *Ammonites cordatus*, *Cerithium*, *Bourguetia*, *Pleurotomaria*, *Astarte*, *Cucullæa*, and *Ostrea* from the Trigonia Beds, and Damon gives a list of fossils from the same neighbourhood.†

The Trigonia Beds and Oolite are exposed again 700 yards west of the station, and at intervals along the straight Corallian scarp past Corton and Rodden. At Merry Hill and west of it the latter forms a bold feature, in places even a small cliff, north of which and some little distance down the dip-slope subordinate scarps of ferruginous grit mark the position of the Trigonia Beds and the Sandsfoot Grits.

Abbotsbury.

The long outcrop of Corallian rocks which we have traced terminates here against a large fault by which Fuller's Earth and Forest Marble are brought up, and at the same time curves round the west end of the Abbotsbury syncline. An outlier of Kimmeridge Clay marks the axis of the syncline, and it will suffice to add that the Corallian series dips from the outcrop on the south and from the fault on the north towards this axis, and that on both sides, as well as towards the west, the upper members of the group form dip-slopes leading down to the Kimmeridge Clay tracts. It so happens that the upper beds have locally assumed the character of an iron-ore, which gives the slopes alluded to a conspicuous red tint.

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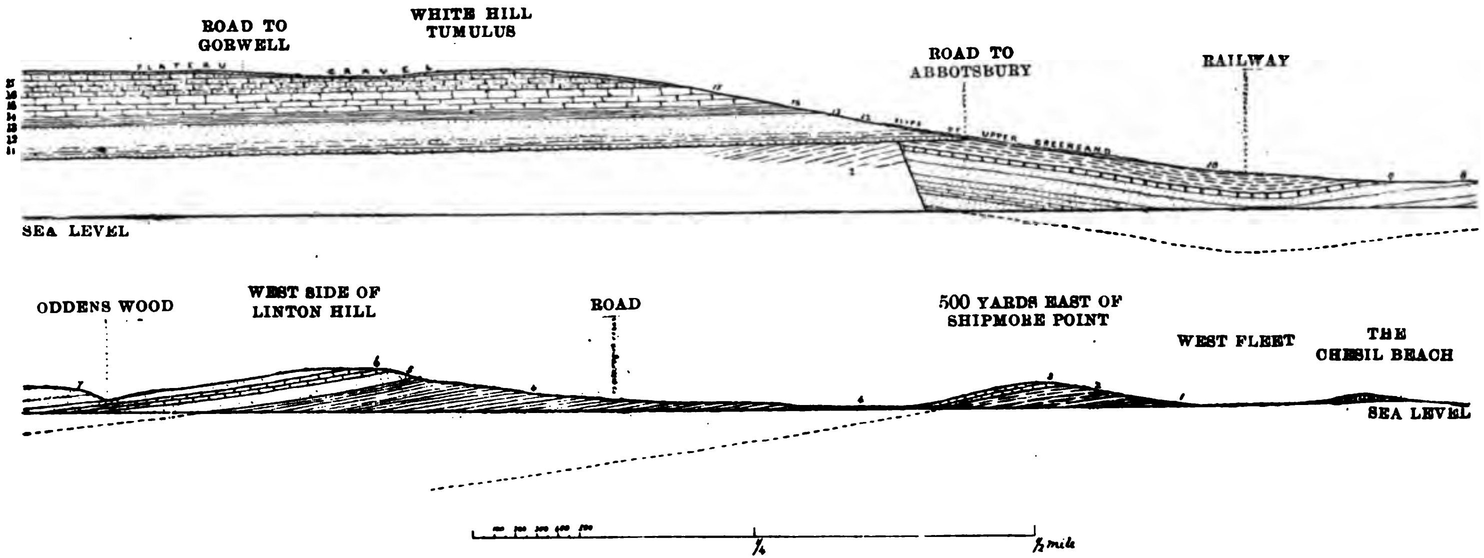
* This cutting was unfinished, and did not expose the Osmington Oolite at the time of Mr. Woodward's visit.

† From a quarry now closed and difficult to identify.

FIG. 68.

Section from the Chalk Downs near Abbotsbury through Linton Hill to the Chesil Beach.



17. Upper Chalk.
16. Chalk Rock.
15. Middle Chalk.
14. Lower Chalk.
13. Grit and Chert. } Upper
12. Sands. } Greensand.
11. Gault.
10. Kimmeridge Clay.
9. Abbotsbury Iron-ore. }
8. Sandsfoot Beds. }
7. Trigonia Beds. } Corallian.
6. Osmington Oolite. }
5. Lower Calcareous Grit }
4. Oxford Clay.
3. Cornbrash.
2. Forest Marble.
1. Fullonian (Fuller's Earth Clay).

The Osmington Oolite continues to form a prominent outcrop, and has been much quarried in this neighbourhood also. In a pit south of Odden Wood blue oolitic limestone is exposed to a thickness of 30 feet, and the Chapel Coppice occupies the site of an old quarry from which stone was raised for building St. Catherine's Chapel, and probably also the Abbey Barn and other buildings. The same bed crops out at the back of Abbotsbury Castle, and has been quarried close up to the fault. Though highly fossiliferous at Osmington, at Abbotsbury it yielded scarcely a single fossil to Messrs. Blake and Hudleston besides *Myacites*, the only others noted being *Pecten fibrosus* and a *Chemnitzia*. Mr. Woodward records also *Ammonites cordatus*, *Cerithium*, *Bourguetia*, *Pleurotomaria*, *Astarte*, *Cucullæa*, and *Ostrea*. (Jurassic Memoir, vol. v., p. 92).

The escarpments of the Trigonia Beds and Sandsfoot Grits form the prominent features of Linton and Chapel Hills, and of the similar ground behind Abbotsbury Castle. On Linton, in the broken edge of the escarpment of the Trigonia Beds, Messrs. Blake and Hudleston noted the following details*:—

Linton Hill.

	Ft.
Thin flaggy limestones with abundant fossils	5
Trigonia-grit with Myacites	2
Strong shelly limestone	
White marl with *Trigonia*	
Thin shelly limestone	
Marl	
Flaggy white oolite	1
Whitish marl	

The lower two beds are thought by them to belong to the Osmington Oolite. From the upper beds they note, in addition to several of the species recorded at Weymouth and Osmington:—

Ammonites plicatilis, *Sow.*
Ceromya inflata [orbicularis], *Ag.*
Anatina, sp. (*Cf.* undulata, *Sow.*)
Myacites decurtatus, *Phil.*
Goniomya v-scripta, *Sow.*
Mytilus jurensis *Röm.*
Pygaster umbrella, *Ag.*
Acrosalenia decorata, *Haime.*

To these Mr. Woodward adds *Natica*, *Cylindrites*, *Isocardia*, and a large *Pinna*.

The second scarp alluded to consists of ferruginous grit with a few small pebbles and spherical grains of iron-oxide. About 15 feet are here exposed, but a considerable further thickness of ferruginous sand and oolitic iron-ore lies above, and is inseparable stratigraphically from the grit in the scarp. The occurrence of the ore attracted the attention of Sedgwick,† and was referred to by Buckland and De la Beche,‡ as well as by subsequent observers. But it was more exhaustively examined by Messrs. Blake and Hudleston, who quote from it the following list of fossils, and and remark that "a feature of the fauna is the presence of brachiopoda, which we have nowhere else met with in the Corallian beds of this district, and from the association of

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* *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 269.
† *Ann. Phil.*, vol. xxvii, p. 350.
‡ *Trans. Geol. Soc.*, Ser. 2, vol. iv, p. 27.

Rhynchonella corallina with *R. inconstans* we may infer that we are really dealing with beds at least on the horizon of the passage-beds to the Kimmeridge Clay." †

Ichthyosaurus (tooth)
Ammonites decipiens, *Sow.*
„ hector, *D'Orb.*
* „ mutabilis, *Sow.*
Belemnites nitidus, *Dollf.*
Chemnitzia pseudolimbata, *Bl. & H.*
„ delia, *D'Orb.*
„ ferruginea, *Bl. & H.*
*Cylindrites.
*Nerinæa.
*Natica.
Pleurotomaria reticulata *Sow.*, (var.)
Alaria.
Natica eudora, *D'Orb.*
Modiola subæquiplicata, *Goldf.*
Arca sublata, *D'Orb.*
Trigonia monilifera, *Ag.* (var.)
Pleuromya Voltzii, *Ag.*
Pleuromya tellina, *Ag.*
„ donacina, *Ag.*
Cardium delibatum, *De Lor.*
Inoceramus, sp.
Pinna pesolina, *Cont.*
Pecten midas, *D'Orb.*
Rhynchonella corallina, *Leym.*
„ inconstans, *Sow.*
* „ pinguis (?), *Röm.*
Terebratula subsella, *Leym.*
Waldheimia lampas, *Sow.*
„ dorsetensis, *Walker.*
* „ ornithocephala, *Sow.*
Echinobrissus scutatus, *Lam.*
Glyphæa ferruginea, *Bl. & H.*
Serpula Royeri, *De Lor.*
„ gordialis, *Goldf.*
Wood.

* Added to this list from specimens collected by Mr. Woodward, and identified by Messrs. Sharman and Newton. The identification of Pterocera from beds in this country is now considered to have been erroneous.

In approaching Abbotsbury the presence of iron-ore is first suggested by the deep-red colour of the grit north of Rodden and at Elworth. On the north side of Linton Hill ore was found containing 32-36 per cent. of metallic iron,† and from this point it may be traced continuously under the Abbey, up Seaway Lane, along the north side of Stavordale Wood to Fuller's Way, north of the Castle Gardens: here it is well exposed, and was found to yield 47 per cent metallic iron.‡ Thence it may be followed northwards up to the fault, by which it is thrown against Forest Marble. Still better sections are presented in the lanes leading into Abbotsbury from the north, and in one of them Messrs. Blake and Hudleston (*op. cit.*, p. 273) measured the following section:—

Section of Ironstone, Red Lane, Abbotsbury.

	Ft.	In.
Loose ferruginous sand ... ... Granular iron-ore, with grains about the size of a millet-seed, and with streaks of ferric hydrate in various directions. Fossils abundant, especially Brachiopoda, as *Rhynchonella corallina* and *Waldheimia lampas*	20	0
Coarse ferruginous sub-oolitic grits in hard cherty bands with numerous *Ammonites decipiens*	2	6
Yellow weathering sand without fossils	2	0
Dark green earthy sub-oolitic rock, highly charged with ferric oxide	1	0
Dark ferruginous sandstones with intercalating variable hard beds, with fossils in the form of casts, including *Exogyra virgula*...	10	0
	35	6

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† *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 274 (1877).
‡ For these figures I am indebted to the late Mr. Manfield, of Portisham.

The section commences close below, if not at the base of the Kimmeridge Clay.

The Abbotsbury oolitic iron-ore is known commercially as "brown hematite." Such ores have generally been formed by substitution of carbonate of iron for carbonate of lime in any calcareous rock, and the oolitic structure in the ore seems to have been due to that structure having been assumed by the calcareous rock at the time of its deposition. In the case of the Abbotsbury ore the original rock must have been an oolitic calcareous sandstone, for quartz-grit enters largely into its composition, while the lime seems to have been provided by the abundance of the molluscan remains. It must, in fact, have resembled some of the limestones associated with the Trigonia Beds, many of which might be equally well described as calcareous sandstones or sandy limestones. That the iron was introduced by a process of replacement is proved by the fact that organisms, which must originally have been formed of carbonate of lime, now consist of carbonate or oxide of iron. Its concentration in this stratum is doubtless connected with the fact of the great impermeable mass of more or less ferruginous Kimmeridge Clay having been laid on top of the bed. A similar relation to an impervious clay is held by the Marlstone, Inferior Oolite, the Westbury, the Claxby, and the Cleveland iron-ores. On the other hand, the Frodingham iron-ore lies between masses of shale and clay, and the Northampton ore rests on Upper Lias Clay and below sands with clay-bands.* It would appear, therefore, that it was immaterial whether the water was held down or whether it was supported by the clay, concentration in either case taking place wherever the nature of the strata in which the water circulated favoured replacement. Subsequently the carbonate of iron, as always happens when that ore is exposed to weathering, was converted into one or other of the oxides by the evolution of carbonic acid gas and oxidation. This change, of course, has taken place principally along outcrops, but at a depth, and especially where protected by coverings of clay, the ore remains in the form of the bluish-grey carbonate.

The condition in which the Abbotsbury iron-ore now presents itself has been minutely described by Messrs. Blake and Hudleston. They found it to consist of:—

"1. Quartz-grit, rounded and subangular, and variable in size

2. Coffee-coloured granules with a smooth surface, for the most part circular and flattened, but occasionally oval, about the size of a pin's head, with fragments of the exterior scattered about like broken egg-shells.

3. A buff-coloured investment, much poorer in iron than the granules, which adheres to the quartz-grains, and sometimes forms a cement to the whole mass; it contains a considerable amount of ferrous carbonate.

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* H. B. Woodward, Jurassic Memoir, vol. v., p. 326.

"The presence of so much silica in the form of quartz is said to detract from the commercial value of the ore; but the small amount of phosphoric acid found in the granules may possibly compensate for this.

"The granules, when broken, are seen to consist of a brown exterior shell, which is largely but not wholly composed of ferric hydrate, and of an interior filled with a buff-coloured powder much poorer in iron. . . . . . After treatment with acid there remains a residue presenting a sphere-on-sphere structure, hollow within, and composed of a uniform subcrystalline material, the greater part being silica. . . . . . A sample of the granules has yielded the following:—

Moisture	1·21
Constitutional Water	11·29
Ferric oxide	73·57
Alumina and soluble silica	4·17
Lime	1·60
Magnesia	1·41
Insoluble in HCl.	5·53
Organic matter, carbonic acid, and loss	1·22
Phosphoric acid	trace
	100·00" *

A portion of the rock taken at random from the road-cutting in the Fuller's Way, north of the Castle Gardens, was pounded up and a part of the powder analysed by Professor G. D. Liveing with the following result †:—

Sesquioxide of iron	43·97
Silica	42·60
Magnesia	1·40
Lime	trace
Common salt	trace
Water	11·88
	99·85

This is equivalent to about 34 to 35 per cent. of Iron in the roasted ore.

Weymouth.

The best sections of the Corallian rocks on the south side of the Weymouth anticline are furnished by the cliffs from Nothe Point to Sandsfoot, and in the Rodwell railway-cutting. The same strata crop out on the shores of the Fleet also, but are not so clearly exposed.

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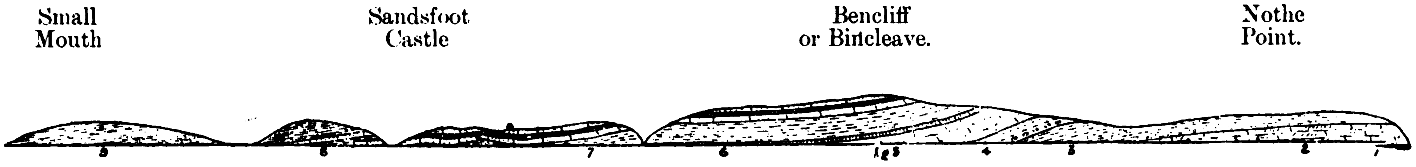
[*] *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 274.

[†] Communicated in 1860 by Professor Liveing to the late H. W. Bristow.

FIG. 69

Section of the Cliffs south of Weymouth (H. B. WOODWARD).

Distance two miles.



9. Kimmeridge Clay.
8. Sandsfoot Grits (with band of clay).
7. Sandsfoot Clay
6. Trigonia Beds.
5. Osmington Oolite.
4. Bencliff Grits.
3. Nothe Clay.
2. Nothe Grits.
1. Oxford Clay.

Beds 2 to 8 are Corallian.

Nothe Point owes its existence to the superposition of the Nothe Grit on the soft Oxford Clay which underlies Weymouth. "The uppermost bed of clay there is surmounted by a thick layer of Ostrea [Gryphæa] dilatata, associated with Ammonites cordatus, Ostrea gregaria, and Serpula tricarinata, which is immediately covered by the sands, with great abundance of Perna quadrata, a very characteristic fossil of the beds throughout this district." (Blake and Hudleston, *op. cit.*, p. 263). The sandstone, especially just south of this point, is traversed by interlacing markings, which are attributed to decayed fucoids.*

The Nothe Clay, which extends along the upper part of the promontory, descends to sea-level on its south side and gives rise to a small bay. Its thickness here is estimated by Messrs. Blake and Hudleston to be about 40 feet, or rather more than in other localities. These authorities quote the following fossils :—

Nothe Clay, Weymouth.

Ammonites cordatus, *Sow.*
Nautilus hexagonus, *Sow.*
Alaria trifida, *Ph.*
Cucullæa contracta, *Ph.* var.
Arca æmula, *Ph.*
Trigonia perlata, *Ag.*
Perna quadrata, *Sow.*
Thracia depressa, *Sow.*
Modiola bipartita, *Sow.*
Lima elliptica, *Whit.*
Pecten fibrosus, *Sow.*
Anomia radiata, *Ph.*
Exogyra nana, *Ph.*
Ostrea dilatata, *Sow.*
„ gregaria, *Sow.*
Serpula tricarinata, *Sow.*

The affinity of this clay to the Oxford Clay has already been noticed (p. 24).

Towards Bencliff (or Bincleave) where the Nothe Clay is overlain by the Bencliff Grits and Osmington Oolite, the following sequence was observed by Mr. Woodward † :—

		Ft.	In.
Osmington Oolite	—Hard fucoidal bed, with scattered oolitic grains	2	0
Bencliff Grits	Fucoidal gritty beds, with clayey nodules	4	0
	Pale grey earthy nodular beds and bluish clays	12	0
	Hard band of calcareous sandstone ...	1	6
	Brown sand and sandstone, with streaks of laminated clay becoming more clayey towards the base, where there occur hard doggers of calcareous sandstone	18	0
Nothe Clay ...	... Blue clay		

Messrs. Blake and Hudleston here collected *Cucullæa corallina*, Ph., *Pecten qualicosta*, Et., *Gervillia aviculoides*, Sow., *Cerithium*, sp., *Lucina*, sp., *Exogyra nana*, Ph.. and *Trigonia corallina*, Ag.

Immediately south of the Bencliff Rocks the Osmington Oolite with *Pseudomelania* (*Chemnitzia*) *heddingtonensis* descends to the beach, followed by the Trigonia Beds, which in the Western Ledges form a pavement studded with Trigonias, chiefly *T. clavellata*.

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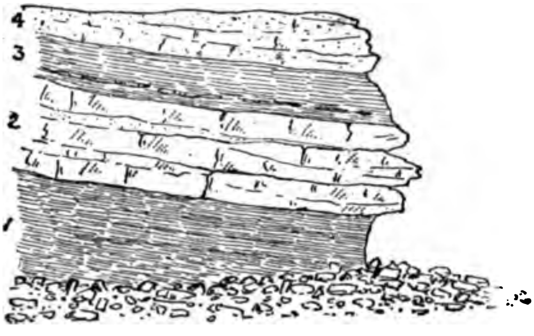
* See also Jurassic Memoir, vol. v., p. 90, on these markings.

† Jurassic Memoir, vol. v., p. 89.

The Sandsfoot Clay above the Western Ledges forms a small undercliff, dominated by a cliff of Sandsfoot Grit, and comes down to the beach in Castle Cove, while the grit forms the point on which Sandsfoot Castle stands. The clay yields *Ostrea deltoidea* in abundance, together with a fauna that is markedly Kimmeridgian in aspect, as previously noticed (p. 24). Its thickness according to Messrs. Blake and Hudleston is 40 feet, but no hard and fast line can be drawn between it and the strata above and below. As remarked by them, it " contains two indurated bands which may be described as a mixture of lime, sand, and clay with a moderate proportion of ferrous carbonate, disseminated pyrites, and carbonaceous matter. These two bands are highly charged with fossils, often of a large size. In the intervening clay the fossils are, on the contrary, dwarfed, as may be especially seen in a large colony of deltoid oysters " (*op. cit.*, p. 269).

FIG. 70.

Section south of Sandsfoot Castle, Weymouth (H. B. Woodward).



Upper Corallian.	4. Red and brown ferruginous sand and sandstones.	Sandsfoot Grits
	3. Blue sandy clay, 6 feet.	
	2. Red and brown ferruginous sandstones, 11 feet.	
	1. Blue sandy clay	Sandsfoot Clay

The Sandsfoot Grit is " divided by a band of blue sandy clay about 6 feet thick, that yields *O. deltoidea*, and might in places be confused with the thicker band of Sandsfoot Clay below." (Jurassic Memoir, vol. v., p. 90.) Messrs. Blake and Hudleston noted the following section, commencing immediately below the " Kimmeridge passage-beds," and extending down to the Sandsfoot Clay :—

" *Section of the Sandsfoot-Castle beds, in descending order* :—

	Ft.	In.
Thin band of ironstone	1	0
Blue marly clay, badly stratified, unfossiliferous	15	0
Glauconitic ferruginous grit . . . impressions of shells ...	6	0
Brown and grey spongy calc-grit of hackly fracture, with numerous interlacing stem-like bars, and hollow tubes of clay. *Myacites* in the natural position	2	2
Blue clay, with a layer of large, almost continuous ironstone doggers passing downwards into the next, and thus becoming more sandy	7	6
Uniform yellow sand . . . The lower part is distinct in some parts as a purplish ironstone with shales. Very fossiliferous	12 to 18	0

. . . . A few feet from the top of the sand we find a bed with *Pinna pesolina* in the position of life. Below this a dark green rock comes on. . . . . The middle and lower portions are most calcareous, and are specially remarkable for the strange interlacing fucoid or sponge-growths. . . . . What we see here, indeed, is not drifted material brought from a distance to be deposited along with its organic remains, but the actual spot on which colonies of fucoids and sponges luxuriated, and on which they left their remains, their most constant Molluscan companion being the great *Lima pectiniformis*." (*Op. cit.*, pp. 270, 271.)

The remains of a crocodilian jaw of unknown genus were obtained from the grits west of Sandsfoot Castle by Mr. E. T. Newton. It was found in a block together with *Goniomya literata* and *Pinna lanceolata*.*

The general section in the cliffs we have just traversed is given by Mr. Woodward (Jurassic Memoir, vol. v., p. 91) as follows:—

		Ft.	In.
Kimmeridge Clay.			
Sandsfoot Grits (See Fig 70.)	Red and brown ferruginous sands and sandstones, shelly in places, with layers of *Ostrea deltoidea*, and fucoidal markings ... ... 8 0 to	7	0
	Blue sandy clay, with hard band near base; layers of *O. deltoidea*	6	0
	Red and brown ferruginous and fucoidal sandstones (slightly calcareous), and greenish clayey sand; with much concretionary iron-ore, and occasional decomposed oolitic grains; beds tinged a purple colour towards the base; they thicken towards the north: *Belemnites*, *Pecten*, *Ostrea deltoidea*, *Serpula intestinalis*, and Plant-remains	11	0
Sandsfoot Clay	Blue, sandy, and calcareous clay, large specimens of *O. deltoidea* abundant: *Astarte*, *Serp. intestinalis*. Near the base there are one or two layers of fissile calcareous sandstone with *Belemnites*, *Exogyra nana*, and small cement-stone nodules	38	0
Trigonia Beds ...	*Trigonia*-bed: bluish-grey sandy limestone with *Trigonia clavellata*, *Gervillia aviculoides*, *Nerinæa*, *Exogyra*, &c.	1	6
	Irregular bands of shelly and sandy limestone, with partings of shaly and sandy marl: *Ammonites*, *Natica corallina*, *Chemnitzia*, *Exogyra nana*, *Myacites decurtatus*, *Mytilus pectinatus*, *Pecten fibrosus*, *Pholadomya æqualis*, Lignite, &c.	10	6
Osmington Oolite	Limestones and shales with *Nerinæa*-bed at base	7	0

The shores of the Fleet do not, as a rule, give good sections. "The Sandsfoot Grits with *Lima pectiniformis* were exposed in the low cliffs south-west of Ryemead Cottages, and beneath them the blue Sandsfoot Clay, with masses of *Ostrea deltoidea*, was exposed. The Trigonia Beds were shown south-west of Wyke, by the bay, and in the cliffs between two lanes leading from Wyke to the Fleet. Westwards we have a good section of the Osmington Oolite, rubbly and shelly oolites, and earthy lime-

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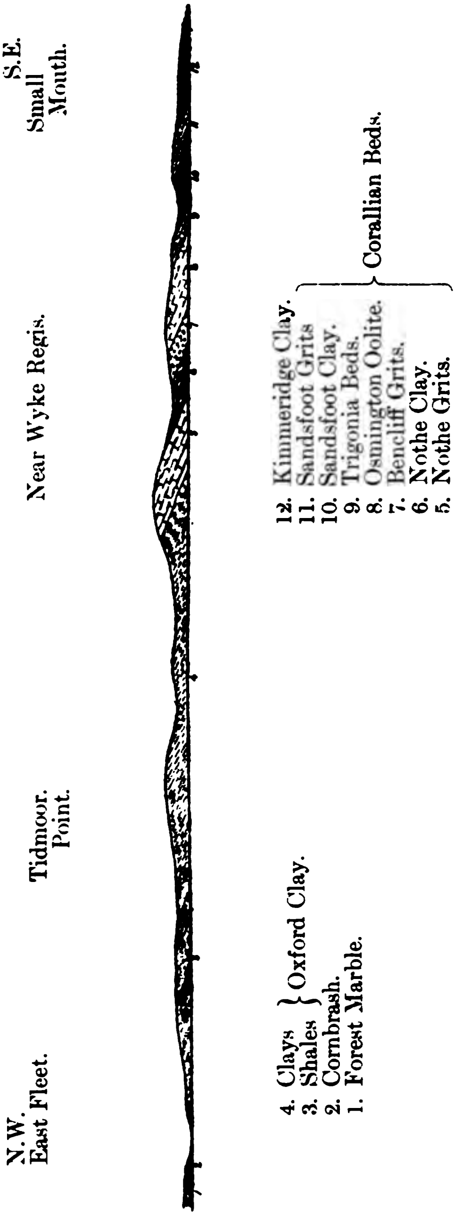
* *Quart. Journ. Geol. Soc.*, vol. xxxiv., p. 398 (1878).

Fig. 71.

Section along the borders of East Fleet, from near East Fleet Village to Small Mouth, South of Weymouth.

(H. B. Woodward). Distance about three miles.



stone, occasionally pisolitic, and with marls and, here and there, sandy shales. *Chemnitzia*, *Nerinæa*, *Natica corallina*, *Littorina muricata*, *Lucina*, *Modiola bipartita*, *Pecten fibrosus*, *Cidaris*, and *Echinobrissus scutatus* were obtained.

"The Bencliff Grits, with doggers and ironstone-concretions, were seen east and west of the main road from Rodwell to Wyke and the Fleet. They were underlaid by clay with nodules, the Nothe Clay: and below by shelly, nodular, and fucoidal calcareous grits, the Nothe Grits. These yielded *Belemnites*, *Gryphæa dilatata*, &c." (Jurassic Memoir, vol. v., pp. 91, 92.)

The best inland section occurs in the railway-cutting at Rodwell, described in detail by Blake and Hudleston (*op. cit.*, p. 267). The Sandsfoot Clay was formerly dug for brick-making, south of the cutting, and at the end of the cutting is overlain by a little Sandsfoot Grit. The Trigonia beds rise on the north side of the southern bridge, the Osmington Oolite about midway between the two bridges, while the Nothe Clay, surmounted by Bencliff Grit, underlies the northern bridge. The Nothe Grit is not here exposed, but can be seen in a brick-pit 500 yards west of the Workhouse, in the form of shelly and ferruginous grit and clay with a thickness of 12 feet, overlying the grey, sandy Oxford Clay. It is visible again in the lanes north of Wyke, but being here weathered and decalcified, takes the form of a white sand. The Oolite has been quarried north and north-west of the same village, while the Sandsfoot Clay can be detected here and there in the sides of the roads.

A well sunk through the Nothe Clays, near Rodwell House, obtained from the Nothe Grits sufficient water to supply a great part of old Weymouth.

Litton Cheney.

The Corallian Rocks are brought in again on either side of the Litton Cheney syncline. South of the syncline they pass eastward unconformably under the Upper Cretaceous Rocks, and 2½ miles to the west are cut off by a north and south fault. Their northern crop, a narrow strip on the north side of the trough of Kimmeridge Clay, is only about half a mile long, and is thrown by the Litton Cheney fault against Chalk and Greensand. Though the whole sequence is present in the south crop, none of the sub-divisions of the Weymouth district can be recognised, except a rock resembling the Osmington Oolite, which has been quarried east of Long Bredy and south-west of Litton Cheney; the dip is northwards at 30°. In the north crop the strata dip southwards at 30° to 45°; a sand pit 200 yards north of Baglake Farm shews oolite, clay and sand.

CHAPTER IV.—UPPER OOLITIC ROCKS.

KIMMERIDGE* CLAY.

The Isle of Purbeck (Plate X.).

We have already seen that this part of the area owes its structure to an anticlinal fold and thrust which are in a direct line with the Brixton anticline of the Isle of Wight. But whereas the oldest strata brought to the surface in the crest of the arch in the Isle of Wight belong to the Wealden formation, the more energetic movement in the Isle of Purbeck has exposed not only the underlying Portlandian strata, but upwards of 600 feet of the Kimmeridge Clay. The clay forms the cliff and foreshore for a distance of 7½ miles (measured along the sinuosities of the coast), and extends inland for a mile or more in the widest part. The village of Kimmeridge is situated on this inlier and has given the name by which the formation is known over a large part of Europe.†

KIMMERIDGE CLAY SAURIANS.

From the Guide to the Department of Geology, British Museum. Part II., p. 32, 1890.

FIG. 72.

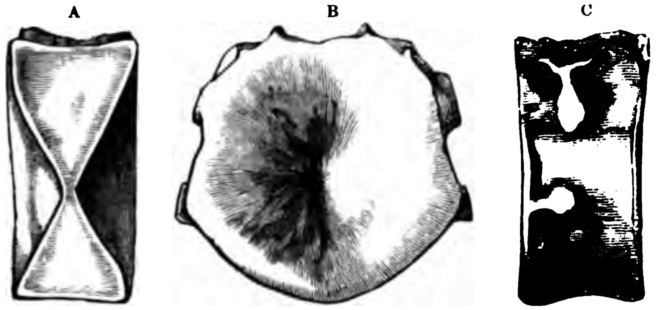


FIG. 72 Ichthyosaurus entheciodon, *Hulke*; Centrum of dorsal vertebra: A. Section, B. Anterior aspect, C. Left lateral aspect.

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* This name has hitherto been spelt with one "m" in accordance with the Ordnance Map of 1811 (Sheet 16, Old Series). The present spelling is adopted from the Resurvey, published in 1892, on Sheet 342, New Series.

† The French Kimmeridgian, however, does not correspond precisely with our Kimmeridge Clay, but ends at the top of our Lower Kimmeridge, while the Lower Portlandian of the French is on the horizon of the lower part of our Upper Kimmeridge. See Hudleston, *Proc. Geol. Assoc.*, vol. xiv., p. 315.

FIG. 73.

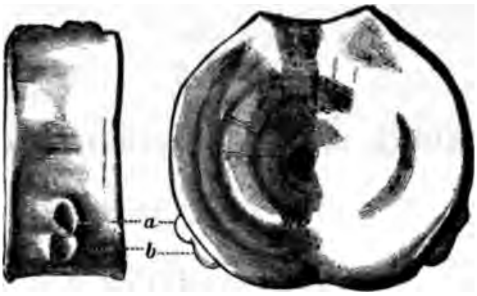


FIG. 74.

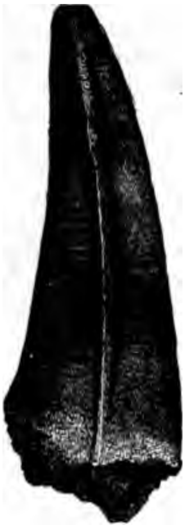


FIG. 73. Ichthyosaurus trigonus, *Owen* ; Centrum of dorsal vertebra : *a*. Upper and *b* Lower costal tubercle.
FIG. 74. Tooth of Geosaurus (Dacosaurus) maximus, *Plien.*

KIMMERIDGE CLAY FOSSILS.

FIG. 75.

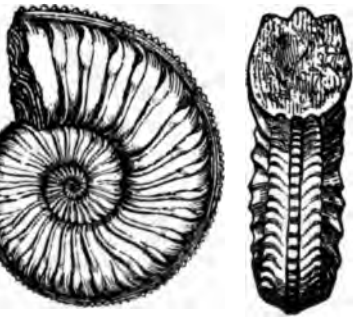


FIG. 75. Ammonites alternans, *von Buch.* ⅔.

FIG. 76.

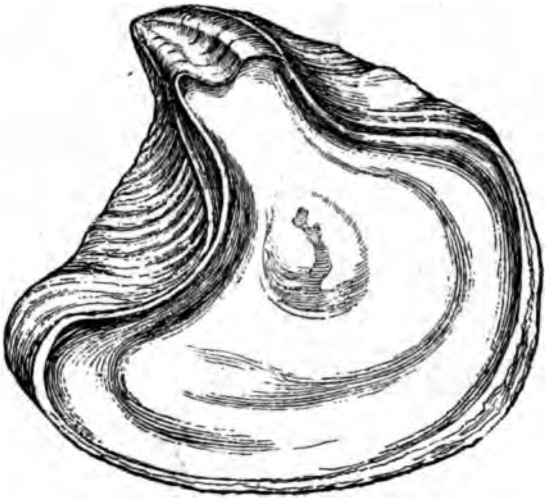
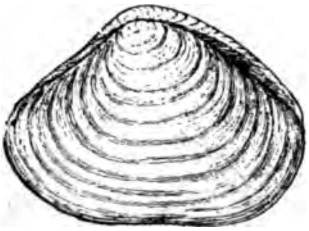


FIG. 78.

FIG. 77.



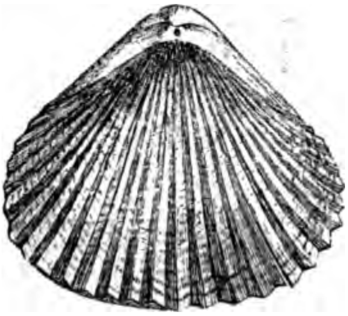


FIG. 76. Ostrea deltoidea, *Sow.* ⅔.
„ 77. Thracia depressa, *Sow.* ⅔.
„ 78. Rhynchonella inconstans, *Sow.* 1¼

KIMMERIDGE CLAY FOSSILS.

FIG. 79.

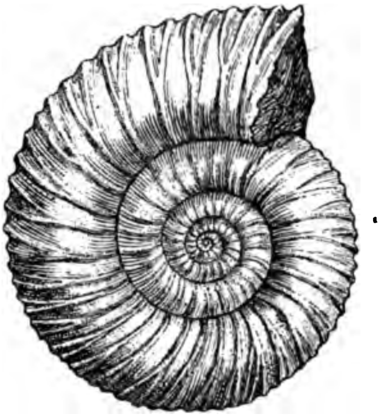


FIG. 80.

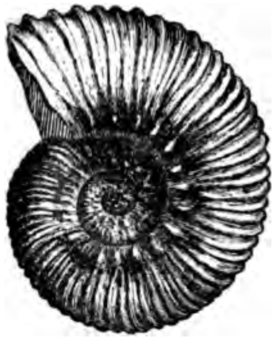


FIG. 84.

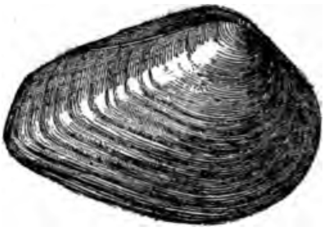


FIG. 81.

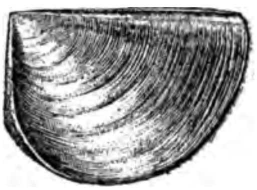


FIG. 86.

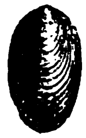


FIG. 83.

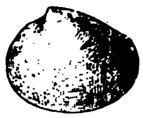


FIG. 82

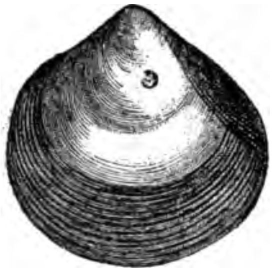


FIG. 85.

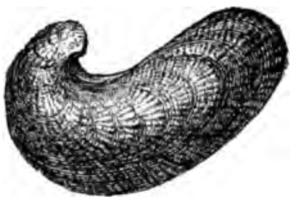


FIG. 79. Ammonites biplex, *Sow.* $\frac{2}{3}$.
„ 80. —— eudoxus, *d'Orb.* $\frac{2}{3}$.
„ 81. Aptychus (Trigonellites) latus, *Park.* $\frac{2}{3}$.
„ 82. Cardium striatulum, *Sow.* Nat. size.
„ 83. Lucina minuscula, *Blake.* Nat. size.
84. Astarte hartwellensis, *Sow.* $\frac{1}{2}$.
85. Exogyra virgula, *Defr.* Nat. size.
„ 86. Lingula ovalis, *Sow.* Nat. size.

The rise of the top of the Kimmeridge Clay from beneath the sea under St. Alban's Head is masked by a wild undercliff composed of slipped masses of Portland Stone, a feature which reappears wherever that rock forms part of a cliff composed of Kimmeridge Clay, but except in such places the sinuous coast affords a clear and continuous section. The dips observable in the foreshore range from N.E. to E., and finally to S.E. and S. in Kimmeridge Bay. In Hobarrow Bay, the point of maximum upheaval, we meet with a general N.W. dip, which increases rapidly until the Kimmeridge Clay plunges beneath the Portlandian rocks of Gad Cliff with an inclination of 20° to 30°. It will be seen, therefore, that the same strata which appear in descending order from St. Alban's Head to Hobarrow Bay reappear in reverse order between that bay and Gad Cliff. (Plate X.).

The foreshore of this part of the coast presents a curious appearance from the vast number of low reefs which run far out into the sea. These Kimmeridge Ledges, as they are called, are due to the alternation of hard shaly stone-bands with soft shale. The Kimmeridge Clay, as a whole, is remarkable for the regularity of its bedding, and the ledges show a corresponding straightness and persistency. At frequent intervals, moreover, the strata are shifted by small faults, almost every one of which can be traced across the foreshore, as far as the tide will permit, by its effect upon the ledges, while their throw can be measured without difficulty in the cliff. Twenty-five faults, with throws varying from 6 inches up to 45 feet, have been noted. They range generally between north and north-east in direction, and eleven of them have downthrows westwards amounting in the aggregate to about 200feet. It is worth noting that the faults generally tend to counteract the effects of the dip. Thus most of those with a downthrow westwards occur in that part where the strata rise westwards, and tend to bring down to the beach again and again beds which had been carried by the dip some distance up in the cliff. Most of those faults, on the other hand, which are downthrows east occur west of Kimmeridge Bay, where the strata rise eastwards; here, moreover, where the rocks are more highly inclined, the average throw of the faults is greater. It may be remarked that the number of faults shewn on this part of the map is partly due to the unusual facilities for observing them. Faults are probably equally abundant in some other parts of the district.

The total thickness of Kimmeridge Clay here seen amounts to 833 feet, according to Prof. Blake. Of this 650 feet are attributed by him to the Upper Kimmeridge, that is, a division of the clay which is characterised by the presence of paper-shales, paper-slabs, bitumenous shales, and cement-stones with clays interstratified; while 183 feet of shales with cement-stones, exposed in Kimmeridge Bay, are assigned to the Lower Kimmeridge on the strength of their containing *Ammonites alternans* with *Exogyra virgula*, though in their shaly character they rather resemble the Upper Kimmeridge.* It is a doubtful point, however, at what horizon the top of the Kimmeridge Clay should be drawn. By Fitton it was taken at about 120 or 140 feet below the base of the Portland Stone, and approximately the same horizon was selected in the original survey of this district. Prof. Blake, however, assigns a thickness of 244 feet to the Portland Sand, and therefore includes in that formation about 100 feet of strata which had been previously regarded as Kimmeridge Clay.

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* *Quart. Journ. Geol. Soc.*, vol. xxxvi., p. 196 (1880).

In the course of the resurvey of the district it became evident that the horizon selected by Fitton was the only one that could be traced inland. The lower boundary, immediately on leaving the cliff-sections, loses itself in a featureless clay pastureland ; the higher line, on the other hand, runs at the foot of a sharply-rising slope leading up to the Portland Stone scarp, and divides in a general way the hill-pasture from the clay-land. The Kimmeridge Clay, therefore, as shown upon the map, includes about 100 feet of strata assigned to the Portland Sand by Prof. Blake, and should reach a thickness of 933 feet according to his measurement. This agrees pretty closely with an estimate made by plotting a section from Broad Bench northwestwards to the Portlandian scarp, which gave a thickness of about 900 feet for the strata we have now included in the Kimmeridge Clay.

The uppermost beds, though generally concealed by landslips, can be examined near Pier Bottom,* at the north end of the crag of Emmit Hill and under Houns-tout Cliff. The passage down from the sand into sandy clay and so into clay or shale is complete, and though in this section there is a hard calcareous band which serves as a base, elsewhere we lose sight of it, and are driven, as already stated, to select a purely arbitrary boundary between the Portland Sand and Kimmeridge Clay. Springs break out and the undercliff of slipped rock commences about 140 feet below the Portland Stone, indicating that a distinctly clayey character has set in at about that height. At about 200 feet below the Portland Stone *Lingula ovalis* was noticed in some abundance by Prof. Blake, a further reason for assigning the beds at that level to the Kimmeridge Clay. On the shore at Chapman's Pool and Egmont Point the clay occurs in characteristic form, namely, as a finely laminated shale with hard stony layers, and almost every bedding-plane covered with crushed specimens of *Ammonites biplex*, *Lucina minuscula*, and *Discina latissima*. Here also there were collected by Mr. Woodward :—*Avicula*, *Ostrea duriuscula*, Phil., *Astarte lineata*, Sow., *Cardium striatulum*, Sow., *Cidaris*, *Rhynchonella*, *Pecten morini*, De Lor., *Arca catalaunica*,(?) De Lor., *A. longipunctata*,(?) Blake, Fish-scales and the hooklet of a cuttle-fish.† For two miles westwards we then cross a series of clays and shales, with thin calcareous stone-bands, some of which are white and finely laminated, all dipping at an angle of about 5° to the east-north-east. At this point the well-known Kimmeridge "Coal" rises from beneath the beach,

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* The valley between St. Alban's Head and Emmit Hill. It is not named on the Ordnance Map, but is so called by Fitton.

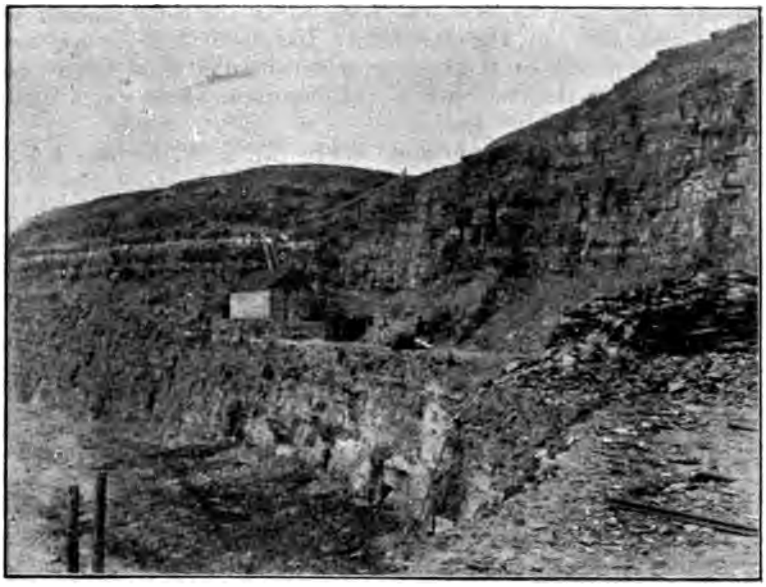
† The occurrence of *Coccoteuthis* here was first noted by W. R. Brodie, *Quart. Journ. Geol. Soc.*, vol. xi., p. 124.

200 yards east of the headland marked on the six-inch map as Clavell's Hard.

The so-called " coal " is a highly bituminous layer of shaly stone, about 2 feet 10 inches thick with its partings, and of a dark brown colour, whence its local name of " blackstone." It breaks with a conchoidal fracture and readily ignites, burning with a bright flame and an offensive smell, and leaving a copious grey ash. When exposed to the weather it is apt to develop a fissile structure, and the laminæ curl up so as to closely imitate layers of brown paper or leather. It is free from pyrites, but contains lenticular masses of calcareous matter.

FIG. 87.

Cliff of Kimmeridge Clay, and Level in the Oil-shale at Kimmeridge.
(From a photograph.)



The Kimmeridge " Coal " has been in requisition from time immemorial. The earliest traces of its use consist of the so-called " coal-money," and of various ornaments and vessels which have been found in barrows and among Roman remains in the neighbourhood of Weymouth, and recently at Silchester. The supposed coins, which occur in the soil in various places in the Isle of Purbeck, are circular discs of two or three inches diameter, and have obviously been turned in a lathe. They are doubtless waste-pieces formed in the process of turning cups or vases, and were thrown aside in heaps, as they are now found.* But as a fuel the coal has been more extensively used, principally in the neighbourhood of Kimmeridge, for which purpose, however, its abominable odour renders it unsuitable.

During the last century alum was manufactured in Kimmeridge

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* See J. C. Mansel-Pleydell, *Proc. Dorset Field Club*, vol. xiii., p. 178, and vol. xv., p. 172.

Bay by Sir William Clavell of Smedmore, and subsequently, when the works were seized by the Crown, a glass-house and a salt-house were erected, the Kimmeridge Coal being used as fuel. Hutchins remarks that "the ruins of buildings and heaps of ashes were, in 1748, the only remains of these works." *

Of late years the mineral property at Kimmeridge has been leased to the Kimmeridge Oil and Carbon Company, by whom the coal has been used for fuel, for improving the illuminating power of coal-gas and for the manufacture of paraffin. It is stated by them that the residual coke or carbon after the distillation of the oil possesses the properties of animal charcoal, and can be employed as a deodoriser, disinfectant, and decoloriser; and that it serves also as a manure. From the oil an insecticide and a preparation for the prevention of mildew, *Oidium*, &c., on vines and other plants has been made. The Blackstone of Kimmeridge Bay, by the same account, is the richest seam yet discovered, and in the laboratory has been known to yield 120 gallons of oil to the ton, or, when distilled on a large scale, 66 gallons to the ton, while the common shale gives about 33 gallons to the ton.†

An analysis of Kimmeridge Coal by Mr. J. W. Keates, F.C.S., gave the following result:—

One ton yielded 9,000 cubic feet of gas, which, burning at the rate of 9·2 cubic feet per hour in a fifteen-holed argand burner, equalled 16 sperm candles consuming 120 grs. per hour. The coal was composed as follows:—

Volatile matter			61
Carbon or Coke	Carbon	13·15	39
	Ash	25·85	
			100

The ash contained:—

Insoluble residue	29·01	per cent.
Peroxide of iron	7·10	„
Silica	21·75	„
Alumina	10·60	„

Notwithstanding, however, the variety of uses to which the coal has been put, it has never paid the expense of extraction, and at the time the resurvey of the district was in progress the works were almost at a standstill.

Just east of the headland of Clavell's Hard the "coal" is thrown down about 6 feet westwards along a line of crush. It then runs along a terrace in the cliff, where there are several levels driven into it, and rising gently westwards, reaches the top of the cliff at the east end of Hen Cliff. There it strikes inland, the outcrop being marked for about 800 yards northward by a line of old surface-workings. Several faults of 5 to 12 feet can be seen in its outcrop in the cliff, all, with one exception, with downthrows westwards. The coal has been worked also by means of a shaft 200 yards from the edge of the cliff.

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* "The History and Antiquities of the County of Dorset," 3rd Ed. (1862), by W. Shipp and J. W. Hodson, vol. i., part iii., p. 556.

† For this information I am indebted to Mr. Charles Beaumont.

Clavell's Hard, or Blackstone Point, one mile south-east of Hen Cliff.

		Ft.	In.
	"Short-joint Coal," not worked but picked up by the villagers	0	6
	Shale	10	0
	Hard calcareous stone-band, formerly used for cement-making	1	6
	Shale	15	0
Kimmeridge Coal	"Black Dirt," or "bastard coal" ...	0	6
	Shale	0	3
	"Blackstone,"	1	0
	Shale	0	3
	Best "blackstone" (Springs issue from this bed)	0	10
	Shale	6	0

From the "coal" Mr. Woodward has collected *Discina latissima*, Sow., *Ostrea læviuscula*, Sow., and *Ammonites varicostatus* (?), Buckl.; and from the shale immediately below, *Serpula*, *Lingula ovalis*, Sow., *Astarte mysis* (?), D'Orb., *Cardium striatulum*, Sow., and *Littorina* (?), together with remains of fishes and shrimps.

About 500 yards west of Clavell's Hard a band of calcareous marl 2½ feet thick rises from the beach. It is worked by driving levels into the cliff, and is sent to Newport, in the Isle of Wight, for making cement. It lies about 60 feet below the "coal," and about 80 or 90 feet still lower there occurs a stone-band which rises at the reef marked as Yellow Ledge on the six-inch map, and reaches the top of the cliff 100 yards west of Clavell Tower; this seems to be Bed No. 38 of Prof. Blake's section, from which he records *Exogyra virgula*, *Ammonites Thurmanni* and other fossils.* From the foot of the cliff J. Rhodes collected *Lingula ovalis*, Sow., *Lucina*, *Ostrea duriuscula*, Phil., *O. læviuscula*, Sow., *Cardium striatulum*, Sow., *Corbula sp.*, *Discina latissima*, Sow., *Exogyra virgula*, Defr., *Astarte mysis* (?) D'Orb., *Ammonites biplex* (?) Sow., *A. eudoxus*, D'Orb., and fish-remains.

The next noticeable stone-band forms Maple Ledge on the north side of Kimmeridge Pier; it is 14 inches thick and dips eastward at 1 in 30 (nearly 2°). One hundred yards east of Gaulter's Gap it is thrown up westwards by a fault, and unfortunately so far up as not to occur in the cliff on the west side of the fault. There being no other marked band by which the displacement of the fault can be determined, the otherwise continuous measurement of the Kimmeridge Clay is interrupted. There is no reason, however, to suspect a large throw, and we may assume that the strata on the west side of the fault, while certainly below, are not far underneath the lowest seen on its east side. Continuing westward we cross a still descending section of shales not unlike those previously described, but containing a fauna which led Prof. Blake to assign them to the "Lower Kimmeridge," *Exogyra virgula*, *Ammonites alternans*, *A. eudoxus*, and *A. longispinus* all occurring abundantly.

Two conspicuous stone-bands interbedded in the shales enable us to determine the displacement of numerous faults shown in this cliff. The upper band, which contains a shale-parting near the middle, forms the reef known as Washing Ledge, and reaches the top of the cliff 350 yards west of Gaulter Cottages. At the same spot the lower band rises from the beach, and being nearly horizontal forms a broad shelf much like a pavement, and known as the Flats. At its west end this ledge is abruptly cut off by a fault, on passing which we find the lower stone-band 20 feet up in the cliff. The dip now being southerly (at an angle of about 2°), and the coast trending south-west, the lower band gradually slopes down to the beach again, and forms a second broad pavement below the Lifeboat Station. This again is cut off by a fault, on the west side of which the stone-band has jumped up 40 feet. Once more it descends gradually to the beach and forms a still more conspicuous pavement known as Broad Bench; the bed here is about 14 inches thick, and is traversed obliquely by meandering little thrust-faults or squeezes with slickensides. On rounding the headland and entering Hobarrow Bay, we notice that a northerly dip sets in, in consequence of which the lower stone-band sinks below the beach, and at the same time the upper, or Washing Ledge stone-band appears in the top of the cliff. About 90 yards further on, however, in the north-east corner of Hobarrow Bay a third fault throws the strata 45 feet down eastwards. On the west side of this fault we recognise the lower stone-band about 50 feet up in the cliff, and here therefore at the foot of the cliff obtain a view of the lowest beds hitherto exposed, and the lowest anywhere seen in the Isle of Purbeck. In them Prof. Blake records *Ammonites alternans* associated with *Exogyra virgula* and *Ammonites biplex*, and remarks that the whole series is here more or less shaly, as it was in the sub-Wealden boring.*

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* *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 200.

The north-westerly dip now sets fairly in, and in walking on towards Gad Cliff we pass in rapid succession all the Kimmeridge strata described above. The lower stone-band runs out to sea in the reef known as Long Ebb, while the upper forms a nameless reef 100 yards further on. Two conspicuous bands of cement-stone can be detected in the cliff of Brandy Bay, and the "coal," about 2 feet in thickness, but more shaly than at Kimmeridge, can be followed to the beach under Gad Cliff. Twenty-five feet above it there is a conspicuous white calcareous band containing about half an inch of "coal," and resting upon 4 to 8 inches more of the same substance. Six feet lower down there are 3½ inches more of "coal." The dip increases steadily from 5° in Hobarrow Bay to 15° and 20° in Brandy Bay, and 30° in Gad Cliff.

The following fossils were collected from shales at Broad Bench by J. Rhodes for Mr. H. B. Woodward† :—

Lingular ovalis. *Sow.*
Pecten lens, var. Morini(?), *De Lor.*
Ostrea duriuscula, *Phil.*
Lucina.
Hinnites.
Exogyra virgula, *Defr.*
Cyprina (?)
Corbula.

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* *Quart. Journ. Geol. Soc.*, vol. xxxvi., p. 196.

† Jurassic Memoir, vol. v., p. 160.

Cardium striatulum, *Sow.*
Avicula inæquivalvis, *Sow.*
Discina latissima, *Sow.*
Astarte lineata, *Sow.*
Arca longipunctata, *Blake.*
Alaria
Aptychus (Trigonellites) latus, *Park.*
Coccoteuthis latipinnis, *Owen.*
Ammonites biplex, *Sow.*
„ eudoxus, *D'Orb.*
„ Kapffi, *Opp.*
„ longispinus, *Sow.*
Fish-remains.

Ringstead Bay and Black Head (Plate IX.).

In the cliffs of this bay the lowest and highest parts of the Kimmeridge Clay are exposed, but there is a doubt whether some of the central parts are not cut out by faults near Holworth. The clay rises from the beach under the great landslips of Chalk and Greensand of White Nothe, and is well displayed under Holworth House (White Nothe on the six-inch map) some hundreds of yards further on. Here, together with the Portland and Purbeck rocks above, it dips at 20°-35° northwards, but a short distance to the east the dip changes to 6° eastwards. Rather less than half-way up the cliff there occurs a stone-band with layers of "coal" at 3 and 6 feet below it. Two hundred and fifty yards west of the house all these strata are cut off by a north and south fault with a downthrow east, the position of the fracture being especially well marked where the harder Portland and Purbeck rocks terminate abruptly against it. On the west side of the fault a stone-band and coal resembling that of the east side occur at the brow of the cliff, while the Portland Stone now crops out at South Holworth Cottages, 350 yards further north.

This cliff is still known as Burning Cliff from the circumstance that the "Coal" ignited spontaneously in 1826 and burnt for some years. There is now but little trace of the fire, the burnt fragments of shale which formerly abounded having almost all been washed away. The fire was in progress when Buckland and De la Beche visited the district, and was thus described by them:* "we have at this moment before our eyes the pseudovolcanic phenomena that are exhibiting themselves . . . . near the east extremity of Ringstead Bay . . . . This pseudovolcanic combustion began in September 1826, and during a period of many months emitted considerable volumes of flame, probably originating in the heat produced by the decomposition of the iron pyrites with which this shale occasionally abounds . . . . This pseudovolcano at Holworth commenced in the face of the cliffs about twenty feet above the sea; its combustion was proceeding slowly when we saw it in September 1829, and it emitted no flame . . . . The extent of the surface of the clay which has been burnt does not exceed fifty feet square. Within this space are many small fumaroles that exhale bituminous and sulphureous vapours, and some of which are lined with a thin sublimation of sulphur; much of the shale near the central parts has undergone perfect fusion, and is converted to a cellular slag. In the parts adjacent to this ignited portion of the cliff . . . .

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* "On the Geology of the Neighbourhood of Weymouth and the adjacent Parts of the Coast of Dorset" (read in 1830). *Trans. Geol. Soc.*, Ser. 2, vol. iv., p. 23.

the shale is simply baked and reduced to the condition of red tiles, like that on the shore near Portland Ferry."

At a distance of about 230 yards from the fault of Burning Cliff there is a second north and south fault with a downthrow east. Its existence is inferred from the fact that the lowest beds of the Kimmeridge Clay appear hereabouts in the foot of the cliff, while its direction is assumed from a displacement seen in the outcrop of the Portland Stone at Holworth Cottages. The propinquity of the base of the Kimmeridge Clay is first suggested by a red irony band which crops out at the mouth of a ravine, and which much resembles parts of the Coral Bed or uppermost zone of the Corallian group (p. 29). Thence for upwards of a mile the Coral Bed can be identified at frequent intervals with the *Ostrea deltoidea*-beds of the Kimmeridge Clay above, forming a low cliff. At Osmington Mills a wedge of Kimmeridge Clay is introduced between Corallian rocks by the complicated trough-fault described on p. 31.

Black Head, to the west of this faulted tract, presents the Corallian and Lower Kimmeridge strata in regular sequence, all, however, dipping northwards at 40° to 60°. The Coral Bed keeps near the foot of the cliff for about two-thirds of a mile, while the "coal," or a band similar to it, can be traced for a short distance in the upper part. The section, however, is obscured by landslips and is incomplete, for the upper part of the formation is concealed by unconformable Upper Cretaceous Rocks.

Portisham, Abbotsbury, and Litton Cheney.

The Kimmeridge Clay outcrop now passes inland to Upway, Portisham, and Abbotsbury, and yields but few noteworthy sections. At Portisham an energetic attempt has been made of late years to turn the "coal" to account. About 1856 it had been discovered in the Portisham Dairy (100 yards west of the Station) at 14 feet depth, and a few tons were got out. A pit was sunk on the east side of the building and intersected the bed at 12 feet depth, but in both cases the works were drowned out. In 1877, the railway-cutting east of the Station having disclosed the outcrop, the "coal" was mixed with clay and about 2,000 tons burnt for ballast. Various other shafts were sunk, but all were overpowered by water, until the Manfield Shaft was made in 1883. This was dry until the "coal" was reached, when a feeder, which yielded at first 11,000 gallons of water an hour, was struck. A very rich oil-shale was met with in the shaft at 46 feet 7 inches depth, but the principal bed at 137 feet, a hard rock-band occurring 33 feet below it. The principal bed gave the following measurements:—

Portisham.	FT.	IN.
Oil-shale	2	0
Clay	1	0
Oil-shale	0	10

The shaft was sunk to a total depth of 189 feet with a boring to a further depth of 126 feet. It is situated 170 yards north of the railway, and an incline was driven to it in the "coal" from the outcrop by the side of the line, the inclination being 1 in 4 (15°). One hundred tons of both parts of the principal bed were sent to Scotland for distillation, but in consequence of the death of Mr. Manfield the trial seems to have been abandoned.

From Portisham Dairy the outcrop runs to Goose Hill Dairy, and then doubles back owing to a change in the dip from north to east and finally to south-east. These agree with the dips observable in the Portland Stone escarpment close by and shew that the strata lie in a synclinal form under the village (Fig. 68, p. 36). Eastwards its crop has been traced to near Coryates, where Mr. A. C. G. Cameron has noted the following section:—

100 yards north of Silly How, Coryates.	FT.	IN.
Shelly shale with nodules	4	6
Oil-shale, chocolate-coloured and breaking out in four-inch plates	1	8
Oily clay	1	0
Shale not bottomed.		

During the search for the oil-shale Mr. Manfield caused a section to be levelled across the Kimmeridge Clay outcrop from Rodden to Portisham, and estimated the total thickness of the formation to lie between 1,100 and 1,300 feet.

It has been already explained that owing to a synclinal arrangement in the strata under Portisham the crop of the "coal" bends back northwards and eastwards. The beds which come to the surface towards Abbotsbury are therefore below the "coal" worked in the shaft; they, however, contain thin bands of the same material, as may be seen in a subway east of Abbotsbury Station. Under the village of Abbotsbury the Portisham syncline is easily traced, the base of the Kimmeridge Clay sweeping round northwards and eastwards, as was the case with the crop of the coal, while a little further west a small outlier lies in the hollow of the same fold. Here, moreover, it can be seen that the syncline is connected with an intra-Cretaceous fault, with a large downthrow south. It should be noted that the Upper Greensand has slipped far down over the Jurassic rocks near Abbotsbury.

At Litton Cheney the Kimmeridge Clay occurs again in a syncline, the eastern extension of which lies hidden under the Upper Cretaceous Rocks of Long Bredy. There are no good sections, but the boundaries can be fixed by reference to the Corallian outcrops on the north and south sides respectively. The dips in the north crop, under Litton Cheney, range from 30° to 45° to the south; those on the south crop are comparatively slight.

The Kimmeridge Clay of Portland will be described in the Chapter dealing with that Island.

CHAPTER V. UPPER OOLITIC ROCKS (*continued*).

PORTLAND BEDS.

THE PORTLAND SAND.

We have already referred to the difficulty of separating the Portland Sand from the Kimmeridge Clay, and to the fact that we have included in the latter formation about 100 feet of strata assigned by Prof. Blake to the Portland Sand, the reasons for so doing being chiefly the exigencies of map-making. The strata thus included under the name of Portland Sand have a thickness of 100 to 120 feet; that is nearly the thickness assigned to the subdivision by Fitton. Upwards they pass into cherty and sandy limestones, which form the lower part of the Portland Stone. This junction is repeatedly exposed at the foot of the limestone-crags.

At St. Alban's Head (Plates x. and xi.) limestone with chert rests on a fine loamy sand with nests of calc-spar and blue clayey bands, passing down into pale-blue clayey sand with light-coloured stone-bands and great concretions. Much of the rock is calcareous, and weathers brown or grey. Some large and nearly continuous concretions near the base were thought by Fitton to represent the great concretions of Shotover Hill, near Oxford; they contain *Thracia* (*Panopæa*) *depressa*.* According to the same authority, *Ammonites giganteus* and *Trigonia clavellata* occur in the Portland Sand in a cross-road above Kimmeridge Farm, and we are here reminded that a bed of limestone

PORTLAND FOSSILS.

FIG. 88.

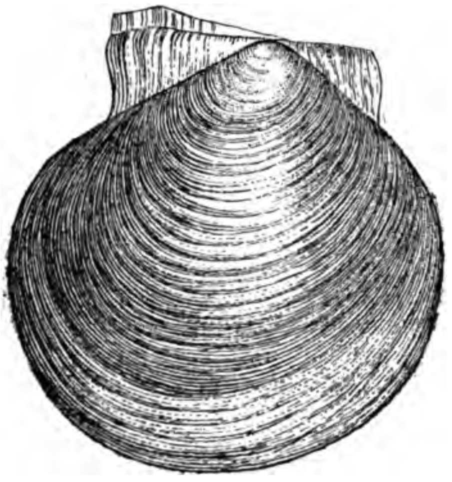

FIG. 89.

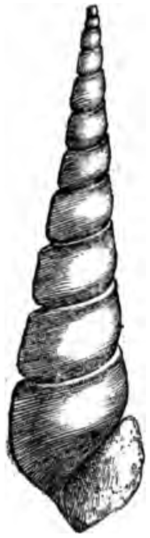

FIG. 88. Perna mytiloides, *Lam.* ½.
,, 89. Cerithium portlandicum, *Sow.* Nat. size (cast).

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* *Strata below the Chalk*, p. 212.

PORTLAND FOSSILS.

FIG. 90.

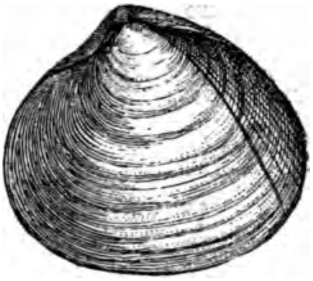

FIG. 91.

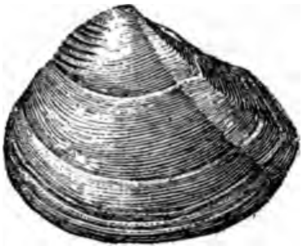

FIG. 92.

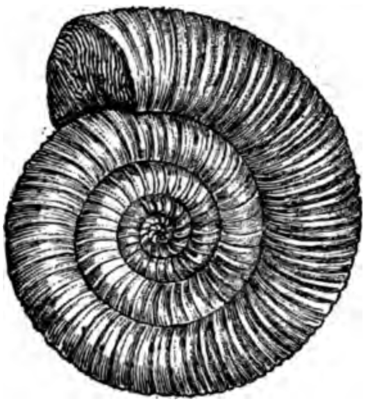

FIG. 93.

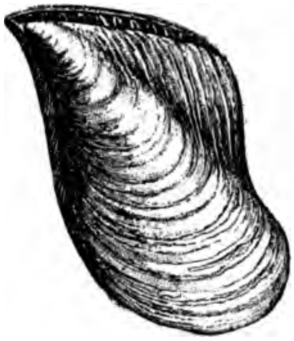

FIG. 94.

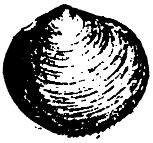

FIG. 98.

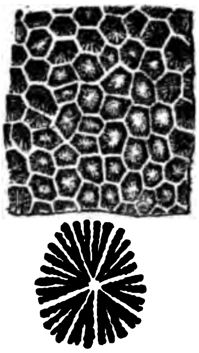

FIG. 95.

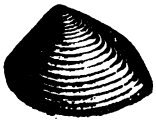

FIG. 96.

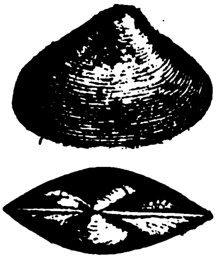

FIG. 97.

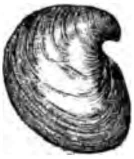

FIG. 90. Cardium dissimile, *Sow.* $\frac{2}{3}$.
„ 92. Ammonites giganteus, *Sow.* $\frac{1}{18}$.
„ 94. Lucina portlandica, *Sow.* $\frac{1}{2}$.
„ 96. Cyprina elongata, *Blake*, Nat. size.
„ 98 Isastræa oblonga, *Flem.* $\frac{2}{3}$.

FIG. 91. Trigonia gibbosa, *Sow.* $\frac{2}{3}$.
„ 93. Pecten lamellosus, *Sow.* $\frac{2}{3}$.
„ 95. Cytherea (Cyrena ?) rugosa, *Sow.* Nat. size.
„ 97. Exogyra bruntrutana, *Thurm.* 2.

containing this great Ammonite, and hardly distinguishable from Portland Stone, runs for some miles in the Portland Sand near Portisham, shewing that the two rocks are no less closely linked together than are the Portland Sand and the Kimmeridge Clay.

A stone-band—probably the one alluded to by Fitton—forms a somewhat conspicuous feature in the steep slope of Portland Sand, especially in Houns-tout Cliff, and has been selected as our arbitrary base to the formation in that part of the district.

At St. Alban's Head Prof. Blake records the following descending section:—Liver-coloured mixture of marl and sand, 39 feet thick: *Ammonites biplex* and *Mytilus autissiodorensis* (both abundant): *Pecten solidus, Trigonia incurva, T. Pellati.* Dark hard sandy marl with numerous small "cement-stones," 42 feet thick: *Exogyra bruntrutana.* Band of cement-stone: 2 feet: *Thracia tenera* abundant. Indurated sandy marl, 30 feet thick: *Rhynchonella portlandica.* Cement-stone, nearly 5 feet. [This is the base of the Portland Sand, as shewn on the map.] Sand with indurated bands and more marly bands, about 126 feet: *Lingula ovalis* rather abundant 40 feet above the base.

From Houns-tout westward the Portland Sand forms the steep lower slope of a scarp of Portland Stone; there is enough shale in it to cause small landslips, and it presents few sections. At Gad Cliff it strikes the coast again, but is difficult of access. *Ammonites biplex* and *Exogyra* are recorded from this locality by Mr. Woodward.

The next exposure occurs at Dungy Head, west of Lulworth Cove, where sands rise above the sea-level for about a quarter of a mile, and, as is usual wherever they occur at or but little above the sea-level, form a shelf on which huge blocks of Portland Stone have lodged.

A better section is presented at Holworth, near White Nothe, where the upper part of the Portland Sands is well seen for a short distance between the fault described on p. 57 and the Gault; here they yielded to Mr. Woodward *Exogyra*, *Mytilus ungulatus*, and *Trigonia*. No noteworthy sections occur in the long sinuous outcrops near Poxwell, Preston, and Bincombe, but at Upway there appears in the sands the thin but persistent band of limestone previously alluded to. It not only contains *Ammonites giganteus* in abundance, but here and there it might be described as an oyster-bed, like the band noted in the Portland Stone on p. 64. The best exposures are in the stream north of Coryates and in a cutting at Corton, from which Damon records:* *Ammonites biplex, Belemnites, Avicula, Cardium dissimile, Exogyra nana, Lima rustica, Ostrea, Perna, Pecten lamellosus, P. solidus, Trigonia gibbosa, T. incurva, Thracia tenera.* This rock-band can be traced past Portisham to the western end of the inlier.

THE PORTLAND STONE.

To this massive rock are due the boldest features of the Dorset coast. The vertical cliffs extending from Durlston Head to

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* *Geology of Weymouth, &c.*, 1884, pp. 83, 84.

St. Alban's Head, and the inland escarpment which includes Emmit Hill, Houns Tout, Swyre Head, Tyneham Cap, and reaches the sea in the fine crag of Gad Cliff, are all the direct result of the resistance offered by the hard limestone to subaerial denudation. In an equally conspicuous manner the structure of the country is brought out by the circus-like escarpment near Poxwell and the outlying plateaus of Portland Stone with their superincumbent loads of Purbeck strata near Preston and Portisham; while, lastly, the well-known features of the Isle of Portland are directly due to the superposition of this stone upon the softer strata beneath. The Portland Stone consists generally of an upper very fossiliferous limestone, about 50 feet thick, and a lower part of about the same thickness with numerous bands of chert. Towards its base it becomes sandy, and tends to graduate into the Portland Sand. Its upward limit, on the other hand, is sharply defined throughout this district, both palæontologically and stratigraphically, though the junction of the Portland and Purbeck limestones is not always obvious at first sight.

Both the limestone and the chert are commonly oolitic, the latter having evidently been formed in such cases by the replacement of carbonate of lime by silica.* "Mr. Teall examined microscopic sections of the oolitic freestone (Whit and Base Beds, Portland); and the Top and Under Freestones, Winspit, St. Alban's Head). These showed oolitic grains, pellets, and organic fragments, with some quartz grains (excepting in Whit Bed). The matrix was clear crystalline calcite (Whit and Top beds), or of a granular or mixed nature (Base and Under beds). The oolitic grains on the whole were not very clearly defined, the concentric structure being apparently obliterated in some cases (Top bed) and obscure in others (Base bed). There were no indications of radiate structure.... The chalky limestones of Upway, Portisham, and Brill consist of fine-grained calcareous matter; and in the Portisham rock there were small and often round patches of colourless crystalline calcite."† A specimen of silicified oolite obtained by Mr. Woodward from the Dancing Ledge quarry, St. Alban's Head, is described by him as "a fine white oolitic rock, closely resembling an ordinary oolitic limestone, but not effervescing with acid." A microscopic examination by Mr. Teall showed the rock to consist "of obscure oolitic grains or pseudomorphs after oolitic grains, and also of sponge-spicules of a coarse branching type now formed of a colourless chalcedony, and having traces of their axial canals sometimes preserved. The matrix appears to be largely formed of deeply coloured opal or chalcedony. This forms zones around the oolitic grains, thus leaving small irregular areas with cusp-like projections, which are now occupied by colourless chalcedony; sometimes it fills up the interspaces entirely." Mr. Woodward adds that "The Chert, as seen in the Portland Beds of Portland, occurs sometimes in even, more commonly in irregular bands; occasionally in smooth lenticular masses; and often in isolated nodules. The nodules as a rule are not so distinct as the flints of the Chalk, but end off in jagged outlines. The chert is often shattered. Cases are met with where the chert appears as inclined bands or ribs, in parallel bands cutting across the bedding, as in cliffs below the Lighthouse on Portland, and again at the western end of Gad Cliff, near Worbarrow.

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* See on this subject W. H. Hudleston, *Proc. Geol. Assoc.*, vol. vii., pp. 183, 184, and Plate 1, Figs. 2-6.

† "Jurassic Rocks of Britain," vol. v., pp. 186, 187.

"In an example of chert from the freestone-beds at Winspit, St. Alban's Head, Mr. Teall observed a few angular grains of quartz, but the main mass consisted of chert containing sponge-spicules with which some calcareous matter was associated." * Dr. Hinde has remarked that, "From the Portland beds no entire fossil sponges are as yet known, but in some of the chert nodules in the limestones on the Isle of Portland and at Upway, near Weymouth, there are numerous detached spicules of *Pachastrella antiqua,* Moore, sp., and of *Geodites,* sp., thus showing that, in part at least, the chert of these rocks is derived from sponge remains." †

Purbeck, Lulworth, and Ringstead (Plates XI., X., and IX.).

The Portland Stone was much quarried in former years, and is still being worked here and there, under the name of "Purbeck-Portland," along the coast east of St. Alban's Head, wherever a vessel can be moored against the vertical cliff. The principal quarries are, or were, at Tilly Whim, Dancing Ledge, Seacombe, and Winspit. The stone worked is the lowest course of the upper non-cherty sub-division It rests on a limestone with large nodules and layers of chert, and an abundance of *Ammonites giganteus.* The "best bed" is thickest at Seacombe, where it reaches 8 feet, with 4 feet of inferior stone above it.

At Durlston Head a complication of small faults, with some twisting of the beds, causes an irregularity in the junction of the Portland and Purbeck strata, which closely simulates an unconformity. On rounding the headland, however (which can be done only by boat), we see that the two are actually parallel and conformable, as the Purbeck beds form the brow of a cliff composed of Portland Stone for some miles, and rest always upon the same horizon of that formation.

In the upper part of the Portland Stone there occurs here an oyster-bed formed of a jumbled mass of the shells of *Perna Bouchardi.* It lies above the building-stone, and can be well seen over the old quarries at Tilly Whim. The floor of these quarries is formed by the lower cherty division, which presents the following section:—

	FEET.
Limestone with abundant lenticular masses and nodules of chert	12
Nodular bed	1
Limestone	9
Limestone with abundant chert, seen to	6

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* Jurassic Rocks of Britain, vol. v., p. 186.

† British Jurassic Sponges, p. 193.

The beds rise at a gentle angle westwards, but are several times thrown down by small faults so as to keep at the same general level. At the Ragged Rocks, however, about 800 yards west of the Lighthouse, the whole of the Portland Stone emerges from the water, and the Portland Sand forms a shelf on which a rough talus of fallen blocks has accumulated. Such a talus recurs wherever the top of the Portland scarp rises to 100 feet above the sea-level, this being about the thickness of stone.

At the west end of the Ragged Rocks (1050 yards from the Lighthouse), a fault which can be seen in the Cinder Bed (p. 96) north of the Lighthouse, cuts the cliff in an east-north-east direction; this fault is probably the same as the northerly downthrow of Durlston Head (Plate xi.), but it here throws the strata down 25 feet only. Beyond it the beds run horizontally for 850 yards, when they are again thrown down westwards by two faults of 12 and 25 feet respectively, 60 yards apart; between the faults the chertless central part of the cherty lower sub-division of the Portland Stone just shows above water, while to the west of them the top of the cherty sub-division is level with the water. Thence the beds rise gently to Blacker's Hole, a hollow in the cliff, due to the meeting of three small faults. From Blacker's Hole westward the strata continue their gentle rise until a second talus of great blocks at the foot of the cliff, similar to the Ragged Rocks, indicates the presence of the Portland Sands; but, as before, they are immediately thrown down again by a fault of 80 feet, which brings the base of the Purbeck group well into the cliff. One hundred and fifty yards further on we reach a quarry and the Dancing Ledge, a broad shelf of the lower or cherty limestones dipping south-east at a angle of 4½°. Three hundred yards further on is the old Cliff Field quarry, and some caves also due to quarrying, while at 600 yards from Dancing Ledge we enter the old Edboro' Quarry, first, however, passing over another north and south fault with a downthrow west of 15 feet. From here onwards for some distance the beds look nearly horizontal, though they really dip seawards at angles of 2° to 3°. Between Edboro' and Seacombe there are two faults only, one of 20 feet downthrow west the other of 4 feet downthrow east. Just east of Seacombe Quarry two faults 70 yards apart let down a wedge of limestone and Purbeck strata 10 feet between them. At Seacombe the best stone is at its thickest, as already mentioned; the occurrence of a white oolitic chert here is noted by Mr. Woodward.* The following section given by Hutchins will serve to show the divisions recognised in the stone by the quarrymen.†

Seacombe Quarries.

	FT.	IN.
Surface, earth	2	0
Shrimp-stone, shelly cockly stone, with shells	5	0
Blue bed : cleaves into three beds	4	0
White cap	3	0

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* Jurassic Rocks of Britain (Memoir of the Geological Survey), vol. v., pp. 189, 190.

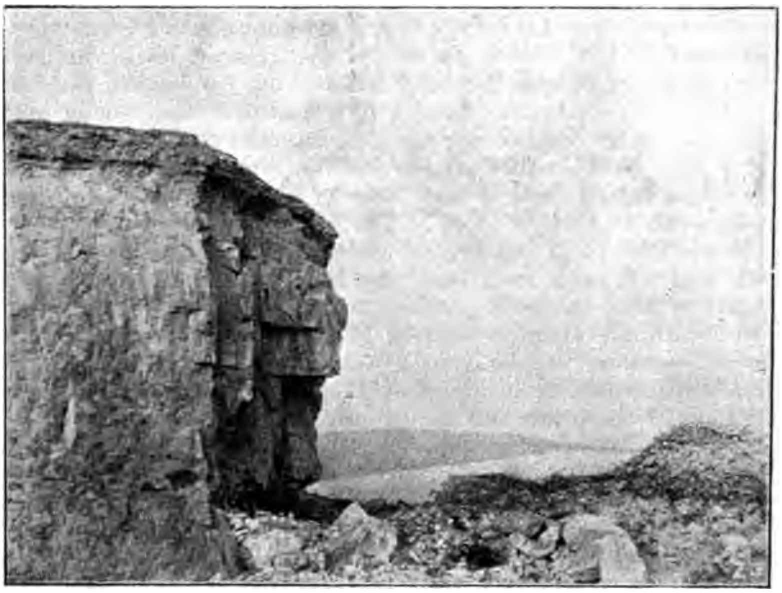
† History of Dorset, 3rd ed., 1863, vol. i., p. 687.

	Ft.	In.
Spangle cap	2	0
Pond freestone (good)	5	0
Flint	2	0
Listy bed...	1	8
Cap stone in three beds, called—		
Listy bed Middle cap House cap	7	0
The before-mentioned is the ceiling of the cliff quarry.		
Underpicking cap (blasted)	2	2
Under freestone—		
1st bed	3	0
2nd bed	6	0
This is a very good stone, and in some of the quarries little inferior to Portland stone.		
Bottom of the quarry a flinty rock, from which to a level with the surface	40	0

Fig. 99.

Purbeck Caps and Portland Stone at Winspit Quarry.

(From a photograph.)



At Winspit the Portland Stone has been extensively worked underground, both in the hillside and in the face of the cliff, where the line of old adits form a conspicuous feature; the stone dips S.S.E. at 1 in 20° (3°). The following is quoted from Mr. Woodward's account (Jurassic Rocks of Britain, vol. v., p. 190):—

		Ft.	In.
Purbeck Beds.	Irregular limestones and clays. (Burr, &c.) ...	4	0
Upper Portland Beds.	Fine-grained white limestone, formerly burnt for lime: SHRIMP STONE	8	0

		Ft.	In.
Upper Portland Beds *continued.*	Hard grey limestone, with *Perna Bouchardi*, &c. Durable stone, used for gate-posts, &c. The shells stand out in relief after long exposure of blocks: BLUE STONE	9	0
	Oolitic limestone. Best stone: TOP, UPPER or POND FREESTONE	7	0
	Bed with white flints: FLINT STONE	4	0
	Soft Freestone. NIST BED... ... 2 ft. to	4	0
	Coarse Limestone with *Ammonites giganteus.* Stone used for breakwaters, not so workable as other beds: HOUSE CAP ... ... 5 ft. to	6	0
	Hard stone with lenticular white cherty stone: has to be blasted out: UNDER PICKING CAP 2 ft. to	3	0
	Oolitic limestone, good stone, used for sinks, curb-stone, &c.: UNDER FREESTONE	6	0
	Cherty stone, known as the "CLIFF BEDS" in distinction from the Freestone series termed locally the "INLAND BEDS."		

The "Shrimp Bed," according to Mr. Hudleston, is so called from the quantity of remains of a small Crustacean.* It is sometimes 9 or 10 feet thick. The "Blue Stone" below is evidently the representative of the Oyster Bed of Tilly Whim. *Trigonia gibbosa* occurs at various horizons here and there in bands in the freestone beds."

A little west of the quarries the freestone beds are about 30 feet thick, and about the same thickness of the lower cherty subdivision is exposed above the sea. Five hundred yards beyond Winspit a fault throws the beds down 15 feet eastwards, while a little further on "ragged rocks" at the foot of the cliff show that the base of the Portland Stone is nearly at sea-level. Half a mile beyond this a change in the dip brings up the Portland Sand abruptly and terminates this long inaccessible cliff.

Prof. Blake records from the upper flintless division of the Portland Stone of these cliffs, *Trigonia gibbosa*, *Pecten lamellosus*, and a brachiopod like *Waldheimia boloniensis*. He remarks on the absence of *Cerithium portlandicum*, so abundant at this horizon in Portland, and on the abundance of *Pecten* and *Perna*, which occur in Portland at a lower horizon.

As soon as the Kimmeridge Clay emerges from beneath sea-level the wild undercliff of St. Alban's Head commences—a scarcely accessible wilderness of slipped masses of Portland Stone. The base of the Portland Stone, however, can be seen round nearly the whole headland, and under Emmit Hill also; it contains not only an abundance of chert-nodules, but so much sand that it may be described as a calcareous sandstone. This and the rest of the cherty subdivision form the crags at the top of the hill, while the building-stones and the base of the Purbeck rocks are exposed in some quarries in the brow above.

On Swyre Head and the Down to the north of it the cherty and sandy lower portion of the Portland Stone form a broad dip-slope. On the other hand, the chertless portion of the formation occupies a narrow tract close along the Purbeck base. Some small quarries have been opened in it for local purposes, principally at the head of the Encombe valley, where the London

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* *Proc. Geol. Assoc.*, vol. vii., pp. 381, 382.

Door Quarry is situated. There the uppermost bed of Portland Stone was worked under the Lower Purbeck tufas and shales, but was too much shattered to be of value.

The long crag of Gad Cliff consists of Portland Stone, with occasionally as much as 40 feet of Lower Purbeck beds over it. The strata all dip inland (northwards) at angles of 25° to 35°, and form a precipice that is characteristic and picturesque, but not suitable for close examination. It may be noticed, however, from a distance that one of the cherty limestones is crossed obliquely by dark lines at fairly regular intervals. From the little cove marked Pondfield on the six-inch map, at the west end of the hill, these lines can be seen to be thin veins of black chert, following small cracks which cross the bedding at an angle of about 45°. Worbarrow Tout in its southern face presents a cliff of Portland Stone of the usual inaccessible character. The base of the Purbeck formation is about half-way up the precipitous part (Fig. 125, p. 98).

The Mupe Rocks mark the reappearance of the Portland Stone on the west side of the bay. There are about fifteen of them, and out of this number four still retain a little outlier of Lower Purbeck rocks. In Bacon Hole there is a good opportunity for examining the junction of the Purbeck and Portland formations, as well as the complete section through the former up into the Wealden (Fig. 126, p. 100). The same junction can be seen in a ledge of the cliff midway between Bacon Hole and Lulworth Cove (Plate III). Here as elsewhere the dividing line is clear and sharp, and the palæontological change abrupt, yet the two rocks are stratigraphically parallel and conformable. West of the Cove, by Stair Hole and Dungy Head, the Portland Stone still forms the lower part of the cliff, but it is not easy of access and is much shattered. Its further course under the sea is marked by the Pinion Rock, Norman Rock, the Man-o'-War (which includes a slice of Lower Purbeck also), to the cliff of Durdle Door, and thence for three-quarters of a mile by the Bull, and the Blind Cow, the Cow, and the Calf Rocks, all portions of a submerged escarpment of vertical Portland Stone running parallel to the vertical Chalk of the adjacent coast.

At Ringstead the Portland Stone has been but little quarried, for it is not only highly inclined, but much shattered by the fault described on p. 57.

Quarry West of Holworth House, White Nothe.

Purbeck Beds. see p. 107.		Ft.	In.
Portland Stone and Sand.	Limestone, crammed with casts of fossils in the upper part	18	0
	Solid limestone with *Trigonia*, &c., bands of chert in the upper half ...	40	0
	Marly limestone	3	0
	Shale	0	9
	Smooth white limestone (like Purbeck)	0	9
	Shale	0	8
	Hard sandy limestone with chert ...	9	0
	Marly limestone	3	0
	Sand with many layers of stone ...	11	0
	Sands, seen to	30	0

The same remark applies to the outcrop near Ringstead Dairy, where the stone dips at 60° to 80° through the combined effect of movements at two different epochs (p. 221).

The exposures in the Upton Valley are poor, but serve to fix the outcrops of Portland Sand and Stone, the Cinder Bed and Middle Purbeck stone-bands, thus leaving little room for error in the other boundary-lines. The unconformity at the base of the Upper Cretaceous rocks is here beautifully illustrated, for the Portland and Purbeck strata, after their brief emergence from beneath the Gault in Ringstead Bay, plunge under that rock near Ringstead Dairy, peep out again 1,400 yards further on in the Upton Valley, but almost immediately disappear under the horizontal beds of Sandy Barrow, once more to start into view near Osmington, always in the same line of strike. Seldom can the folds of an older formation be so completely followed under the mantle of a newer and unconformable group of rocks.

Poxwell to Portisham.

At Poxwell the ground furnishes a beautiful example of the dependence of physical feature on geological structure. A sharp anticline, with dips of 40° to 65° and of 25° to 30° on its north and south sides respectively, brings up an oval inlier of Portlandian strata along the middle of a tract of Purbeck rocks. Round the inlier runs an almost continuous wall-like scarp of Portland Stone, while within it there are undulating meadows underlain by the softer Portland Sand. This pretty hollow, which is suitably known as Poxwell Circus, is about a mile and a quarter long and from two to three hundred yards broad.

Near Bincombe and Sutton Poyntz the anticline passes into a sharp unicline; thus the Portlandian beds, which dip at 60° or 70° northwards close along the Ridgeway Fault, suddenly become nearly horizontal about 100 yards from it, and form the plateaus of Chalbury and other hills.

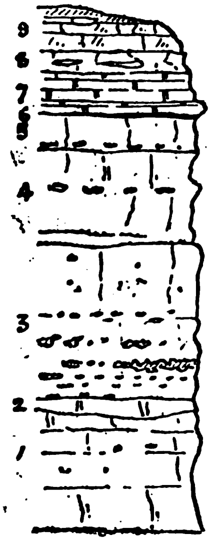
Ammonites giganteus occurs abundantly along these outcrops, and at Greenhill Barton there is an oyster-bed like that of Tilly Whim.

Quarry on the south-west side of Chalbury Camp.

		Ft.	In.
Lower Purbeck.	Shales and laminated limestone, in part "broken" (p. 107).	6	0
	Black earth with lignite, undulating; passing down into ... ... 1 ft. to	2	0
	Earthy brown limestone with brown chert, very irregular	7	0
	Hard tufa weathering out into great blocks on the hill-sides ... 2 ft. to	5	0
	Dirt ... ... 1 in. to	0	2
	Tufa...	1	0
	Dirt	0	½
	White banded limestone...	2	0
Portland Stone.	Fossiliferous limestone	4	0
	Line of chert nodules.		
	Limestone	11	0
	Band of chert ... ... 3 in. to	0	6
	Limestone, about	20	0
	Limestone with many great nodules of chert, base not seen	5	0

At Bincombe the complicated disturbances described on p. 223 bring up some of the Middle Oolites. Passing over these for the present we pick up the Portland Stone outcrop 160 yards west of the Church. The rock dips northwards at 40° to 70°, but flattens in the Knoll, as at Chalbury, into a nearly level plateau. Hereabouts the unicline becomes less intense, and at the same time diverges from the Ridgeway Fault; a little further west, in fact, it can be seen to be the southern lip of a syncline, which has been subsequently crossed at an oblique angle by the post-Cretaceous Ridgeway Fault. On the south side of the syncline the Portlandian rocks form a continuous scarp from Upway to Portisham, while on its northern side the stone is shown in two small inliers cut through by the Ridgeway Fault.

Fig. 100.
Section at Upway.
(H. B. Woodward).



The extreme whiteness of the cherty beds forms a conspicuous feature in the Portland Stone of Upway; at a short distance they are not distinguishable from Chalk-with-flints. The chertless building-stone above is here but 3 feet thick; it contains *Trigonia* in abundance, as is generally the case in the neighbourhood. Above it, with the usual sharp demarcation, lies the basement bed of the Purbeck group, the general succession being as follows according to Mr. Woodward (Fig. 100):—

		Ft.	In
Lower Purbeck Beds.	9. Earthy marl and limestones.		
	8. Marl with seams of chert	2	6
	7. White fissile and somewhat sandy limestone, irregular	4	6
	6. Dirt Bed, with stools and trunks of trees 2 in. to	1	0
	Thin bands of limestone with Fish-remains, *Paludina*, and *Archæoniscus*...	1	0
Upper Portland Beds.	5. Sandy limestone, with black specks, slightly oolitic, and very shelly here and there like Roach	3	0
	4. White chalky limestone with chert-bands; *Ostrea* and *Perna* abundant in upper bed, also *Trigonia*, *Lucina portlandica*, &c. ...	8	0
	Chalky limestone with small nodules of chert scattered through the middle and lower part	6	0
	3. White chalky rock, with many black and white flint or chert layers, *Ammonites* ...	7	0
	2. Hard grey and yellow sandy limestone ...	0	10
	1. White chalky rock, with shelly fragments in places and a few irregular flints	10	0

The beds are subject to many changes in thickness and character. Bed No. 7 in the Purbeck Series showed very irregular structure, and other Purbeck Beds were bent in places.

The stone was formerly worked at Portisham but has been given up in favour of the Lower Purbeck limestones. The following general section was noted by Mr. Woodward:—

Portisham.

			Ft.	In
" Purbeck Beds :—[*See* p. 110.]				
Upper Portland Beds.	Hard slightly oolitic limestone	about	5	0
	Chalky series, with beds and nodules of chert	"	23	0
	Earthy and shelly limestone: Serpulite-bed	"	6	0
Lower Portland Beds.	Soft beds (not seen)....	about	40	0
	Bands, more or less concretionary, of hard grey speckled limestone with small *Exogyra*			
	Rubbly beds of soft earthy limestone, with casts of *Cardium*, &c.			
	Brown and greenish-grey calcareous sands			

"The basement-bed of the Portland Stone yielded *Ammonites*, *Natica*, *Pleurotomaria*, *Cardium dissimile*, and *Trigonia*." (Jurassic Memoir, vol. v., p. 196.)

The description of the Portlandian strata of Portland is reserved for the Chapter on that island.

CHAPTER VI.—UPPER OOLITIC ROCKS (*continued*).

PURBECK BEDS.

Relations of the group with strata above and below.

This group of strata, like several others, takes its well-known name from the district under description, to which, indeed, in one form of development it is almost confined, for Purbeck rocks of the type characteristic of the Purbeck area do not extend beyond Wiltshire and Buckinghamshire towards the north, nor further than the northern provinces of France in the opposite direction. In the district now under consideration they reach a thickness of 396 feet (Swanage), but dwindle westwards to 189 feet (Ridgeway).

Some of the most prominent peculiarities of the formation consist in its fresh-water origin and abundant fresh-water or estuarine fauna, but above all in the fact that it encloses one or more forest-grown land-surfaces. The group, however, is not wholly fresh, but includes estuarine and even true marine strata.

The sudden transition from the purely marine Portland Stone to the wholly fresh-water Lower Purbeck might have been expected to have been conspicuously marked by a lithological change, or by a stratigraphical break, but as a fact the exact plane of separation between the two is not always easy to fix at first sight. The difficulty arises from both rocks being massive light-coloured limestones, both sometimes oolitic, and more or less welded together. A brief examination, however, has never failed to show that there is a sharp divisional plane between them, and that not only do they part most readily, in spite of the welding, along that plane, but that their characteristic fossils (if we except Ostracoda) never transgress it.*

The passage from the Purbeck group upwards into the closely akin Wealden formation is on the other hand complete, the line between them both palæontological and lithological being purely arbitrary. Under these circumstances it seems somewhat unfortunate that the Purbeck strata should be classed as Jurassic, while the Wealden are included in the Cretaceous System. The history of the classification is briefly as follows:—

The Purbeck group was classed as Upper Oolitic in 1822 by Conybeare and Phillips,† but in 1824 Webster remarked that "The most abundant of the small univalves and bivalves in the Purbeck beds are the same as those in the Hastings rock, which contains scarcely any other shell. Beds of the latter are quarried near Battle Abbey in Sussex, having a very close resemblance to some of those in Purbeck, and like them are separated from each other by shale. These and other circumstances may lead us to unite the Purbeck beds, the Hastings beds, and the Weald Clay into one group; while the same reasons will tend to remove the Purbeck beds from the Portland rock, which contains a suite of marine shells only."* Fitton in 1827† adopted this suggestion without hesitation, and grouped the Weald clay, Hastings sands, and Purbeck strata together under the name of Wealden, leaving the Portland Stone in the Oolitic Series.

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* A supposed case of alternation of Portland and Purbeck strata at Swindon has been disproved by Prof. J. F. Blake. *Quart. Journ. Geol. Soc.*, vol. xxxvi., p. 203 (1880). There is, on the contrary, evidence of unconformity between the two in that neighbourhood. It has been said that at Wockley in the Vale of Wardour "both strata and included fossils shew a gradual passage from Portland to Purbeck conditions." *Quart. Journ. Geol. Soc.*, vol. l., p. 51, 1894. The explanation of this statement is supplied by Mr. Woodward in the Middle and Upper Oolitic Rocks of England (Geol. Survey Memoirs) p. 270, 1895, where he shews that the true base of the Purbeck had not been identified, and that consequently Purbeck fossils had been regarded as belonging to the Portland Stone.

† *Outlines of the Geology of England and Wales*, p. 165, &c.

This classification remained undisturbed until 1850, when Forbes‡ published the result of a visit to Dorset made for the purpose of investigating the distribution of the Purbeck fossils *in situ*, while the mapping of the district by Bristow was in progress. He then recorded the occurrence in the "Cinder-bed" of a *Hemicidaris*, "a genus characteristic of the Oolitic period" and further remarked that an examination of the specimens from the Hastings sands and Wealden in the Museum of the Geological Society and in the cabinet of Dr. Mantell led him "to believe that the fauna of the middle and upper division of the Wealden series is, so far as species are concerned, almost entirely distinct from that of the lower or Purbeck division." He concludes that the true position of the Purbeck strata is in connection with the Oolitic or lower, and not with the Cretaceous or upper division of the Secondary rocks. In the discussion on this paper Prof. Owen§ stated that all the large Wealden Reptilia except the Iguanodon were Oolitic and not Cretaceous.

Since that date the inclusion of the Purbeck in the Oolitic series has been accepted in the publications of the Geological Survey and by other writers generally. In course of time, however, as it became recognised that no stratigraphical line could be drawn between Wealden and Purbeck, various compromises were attempted, and a separate group under the title of Purbeck-Wealden, corresponding to the Wealden of Fitton, was reintroduced by Topley. The same author, in conjunction with Mr. Jukes-Browne, stated in the Report to the International Geological Congress on Classification and Nomenclature (Cretaceous) that "the separation of Purbeck from Wealden is a mistake due only to the occurrence in Purbeck of one or two Oolitic forms of marine life. This we should in any case expect, because Purbeck is on borders of Jurassic time, if not actually in it. The separation from Wealden is unnatural."‖ In 1894, however, Messrs. Andrews and Jukes-Browne stated their opinion that there was a discordance between the Wealden and the Purbeck in the Vale of Wardour,¶ but in a visit paid to the vale during that year for the purpose of further investigating the question, Mr. Woodward and I obtained evidence that there was perfect conformity between the two there, as elsewhere.

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* Observations on the Purbeck and Portland Beds. *Trans. Geol. Soc.*, Ser. 2, vol. ii., p. 44., 1826.

† Strata below the Chalk. *Trans. Geol. Soc.*, Ser. 2., vol. iv., pp. 105 and 159.

‡ *Rep. Brit. Assoc.* for 1850. Sections, pp. 79-81.

§ *Edin. Phil. Journ.* vol. xlix., p. 313 (1850).

‖ Congrès Géologique International, Compte Rendu de la 3me. Session, Berlin, 1885, p. 453.

¶ *Quart. Journ. Geol. Soc.*, vol. l., p. 48. (1894).

The conclusion, therefore, has gradually become inevitable that neither palæontologically nor stratigraphically can the Purbeck be separated from the Wealden formation. We return, in fact, to the classification proposed by Webster and adopted 70 years ago by Fitton, probably the greatest authority on the Secondary rocks that the world has yet seen. The exigencies, however, of classification, and the fact that the Purbeck-Wealden does not possess sufficient importance to stand by itself, compels us to place it in either the Oolitic or Cretaceous system. In discussing this question it is necessary to take a somewhat wider view of the relations of the group.

It was suggested in 1843 by Murchison that the Wealden, with the exception possibly of the uppermost estuarine strata, ought to be classed with the Oolitic system,* and in 1850 we have Professor Owen's statement as to the Oolitic affinity of the Wealden reptiles. After the lapse of forty-six years this has received confirmation from Professor Marsh, who remarks that if he had found the vertebrate fossils of the Wealden of this country in the Rocky Mountains, he would certainly have called them Jurassic, and that even after visiting the Wealden localities of this country and the Continent, he can find no reason for doing otherwise. He believes the age of the Wealden to be worthy of careful reconsideration by English geologists.† Mr. Smith Woodward arrives at a similar conclusion from a study of the Wealden fish. "All the known English Wealden fishes are survivors of typically Jurassic genera, except Neorhombolepis and Cœlodus, and these are their little modified representatives. . . . . In fact the Wealden estuary seems to have been the last refuge of the Jurassic marine fish-fauna in this part of the world."‡ The same story is told by the plants, and Mr. Seward concludes that "it would be difficult to point to any well-marked or essential difference between the plant-life of the two periods. The evidence of palæo-botany certainly favours the inclusion of the Wealden rocks in the Jurassic series."§ Prof. Pavlow, on the other hand, leaves the Wealden group in the Lower Neocomian division, correlating it with the Claxby Ironstone and upper part of the Spilsby Sandstone of Lincolnshire; the Purbeck beds he places in his Aquilonian (or upper division of the Jurassic), correlating them with the lower part of the Spilsby Sandstone of the north.|| He remarks, however, at the same time, that a sub-division in Russia, to which he gives the name of Petchorian, and to which the Wealden

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* *Proc. Geol. Soc.* Vol iv., p. 175. 1846.

† *Geol. Mag.*, 1896, p. 8. See also *Nature*, vol. 53, p. 436. (1896).

‡ *Geol. Mag.*, 1896, p. 70. See also *Proc. Zool. Soc.*, 1890, p. 346.

§ Catalogue of the Mesozoic Plants in the Department of Geology, British Museum (Natural History). "The Wealden Flora, Part II., Gymnospermæ," 1895, p. 240.

|| *Quart. Journ. Geol. Soc.*, vol. lii., p. 542. (1896).

group would at least in part correspond, is of doubtful affinities, and might for local convenience be classed as Jurassic. So far there seems to be much in favour of a Jurassic alliance for the Purbeck-Wealden group, and no strong reason against it.

Similar arguments, however, may be urged against selecting the top of the Wealden as the upper limit of the Jurassic system. Stratigraphically in the south of England this line is well defined. Throughout the Isle of Wight, where the relations of the Wealden and Lower Greensand are fully exposed, there is a complete break at this horizon, with not only an abrupt change from an estuarine to a purely marine fauna but with distinct signs of erosion. The same relation holds good in East Dorset, and is not demonstrably absent further west, in Worbarrow Bay. Throughout the south-east of England, where, however, sections are extremely scarce, the line appears to be equally well marked. In the absence of the Lower Greensand, as in West Dorset, the Wealden strata are overlain unconformably by Upper Cretaceous Rocks, and the line is there in every respect the most suitable that could be selected for an important division.

The change of fauna, however, between Wealden and Lower Greensand points to an abrupt change of physical conditions, such for example as the invasion of an estuary by the sea, rather than to any great lapse of time, and it is especially significant that in the north of England, where the freshwater and estuarine type is absent, a stratigraphically continuous series of marine strata lies between the Upper Cretaceous and the Kimmeridge Clay, the only breaks occurring at the top and bottom of this marine series. Here, therefore, we must have the marine equivalents of the terrestrial and estuarine Purbeck-Wealden group, and should have an opportunity of fixing the upward limit of the Oolitic fauna. It was pointed out in 1887 by Mr. Sharman that the fossils of the lower part of that series "form a very distinct group with strong Oolitic affinities," * and this conclusion has since been confirmed by Professor Pavlow and Mr. Lamplugh, who in spite of the continuity of the sequence of strata, and well-marked top and bottom of the marine series alluded to, find it necessary on general continental evidence to place a portion of it in the Oolitic system,† leaving the upper part in the Lower Neocomian of the Cretaceous System—a classification which is obviously not in accordance with the well-marked local stratigraphical evidence.

But if the Wealden also were included in the Oolitic system we should be in a similar dilemma, for so far as his evidence goes at present, Mr. Lamplugh correlates the lower part of the Lincolnshire marine series (the Spilsby Sandstone or Zone of *Belemnites lateralis*) with the Purbeck, while the Tealby Clay (Zone of *Bel. jaculum*) may represent the Wealden.‡ Whether this correlation be exact or not we should still be drawing our Cretaceous base-line in the middle of an indivisible series of strata.

It need hardly be considered what would be the result of including the Lower Greensand also in the Oolitic series, and thus utilising the great stratigraphical break at the base of the Upper Cretaceous as the boundary of a system. The Lower Greensand of English geologists represents the *Aptien* (or upper part only of the Lower Cretaceous) as understood on the Continent, the whole of the Continental *Neocomien* lying below it. The *Neocomien* may therefore be represented in this country either by the Wealden or by the break between Lower Greensand and Wealden to which I have alluded. The fact that the two formations are in the one area fresh-water, and in the other marine, renders proof of their contemporaneity most difficult, but if, as has been stated, marine and fresh-water strata of this age alternate in Germany and France, the necessary evidence may be forthcoming. At any rate it is certain that to draw the upper limit of the Oolitic system above the Lower Greensand would place us in disagreement with the well-established grouping of the Lower Cretaceous Rocks of the Continent.

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* Geology of East Lincolnshire (Geol. Survey Memoir), 1887, p. 141.

† Argile de Speeton. *Bull. Soc. Nat. Moscow*, vol. v.

‡ *Quart. Journ. Geol. Soc.* vol. lii., p. 213 (1896).

The fact is that we are dealing with a set of rocks that taken as a whole have about equal claims to be considered either Oolitic or Cretaceous. They have affinities with both, but on the other hand they possess in themselves a character that is found in neither of those systems where typically developed. The Oolitic rocks for example are purely marine in the south of England as far up as the top of the Portland Stone, but above that rock there follows a series in which fresh-water and estuarine conditions alternate with salt or brackish water, and it is not till we reach the Lower Greensand that we regain a purely marine fauna. A classification into marine and estuarine thus becomes compulsory in the region where those conditions occurred. It is of course local and breaks down even in other parts of England, but at the same time it represents the true relations of the rock-groups to one another in the very region which displays their typical development and furnishes them with their names. These relations are expressed in the following table :—

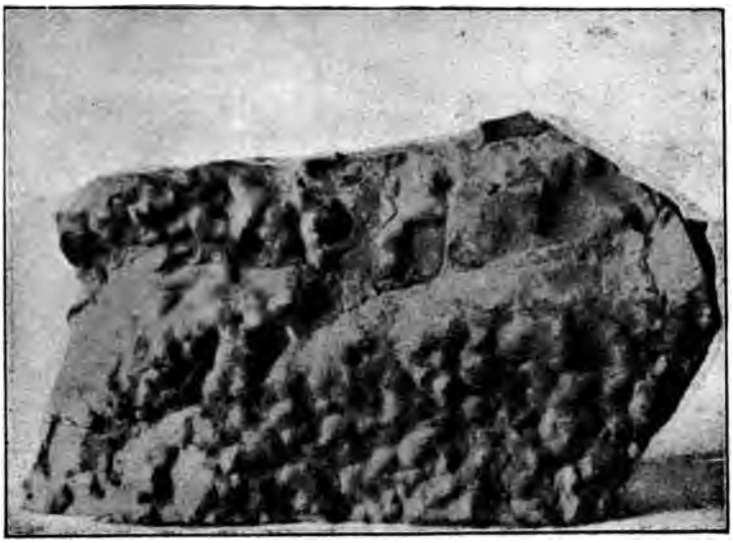
Formations. South of England.	Conditions of deposition.	Affinities.	Equivalents in the North of England.
Chalk ... ... Upper Greensand and Gault	Wholly marine	Cretaceous	Chalk Red Chalk and Carstone
Break.	——	——	*Break.*
Lower Greensand ...	Wholly marine	Cretaceous	Tealby Series and Spilsby Sandstone ; a stratigraphically continuous series of marine deposits with Oolitic affinities in the lower part
Palæontological break due to sudden change of conditions			
Wealden ... ... Purbeck	Estuarine-marine alternating with and passing down into freshwater and terrestrial	Oolitic as relates to the plants, reptiles, and marine molluscs	
Palæontological break due to sudden change of conditions	——	——	*Break.*
Portlandian ... Kimmeridgian, &c.	Wholly marine	Oolitic	Kimmeridgian, &c.

That the most important break in the sequence should be ignored in making the division between the Cretaceous and Oolitic Systems is unfortunate, but seems inevitable when the Continental sequence is taken into account. So far as the region described in the Memoir is concerned, the unconformity at the base of the Gault constitutes the only marked interruption in the sequence of deposits, if, as has been suggested, the palæontological breaks between Lower Greensand and Wealden, and between Purbeck and Portlandian were due merely to a change in the physical geography of the region. This unconformity is one of the most important features in our Secondary rocks, and has not yet received fit recognition.

Lithological Character.

Lithologically parts of the Purbeck strata resemble the Rhætic Beds and Lower Lias of the neighbourhood of the Bristol Channel, as noted by Mr. Woodward. He remarks on this subject that "the grey marls with gypsum, the black shales with 'beef,' a band with rude arborescent markings (recalling the Cotham Marble), and occasional beds like White Lias, are all to be found in the Purbeck strata of Dorsetshire .... The band with the rude arborescent markings occurs in the 'Soft Cockle Beds' of Bristow's section,* and about the horizon marked by him as a 'Hard brecciated Limestone,' above the 'Soft blue shaly Marls' that contain the main masses of gypsum. My attention was first attracted by small slabs on the beach, for these showed the mammillated surface shown in Fig. 101, that is so characteristic

FIG. 101.



Mammillated surface of Limestone (Fig. 102), *Lower Purbeck Beds, Durlston Bay.*

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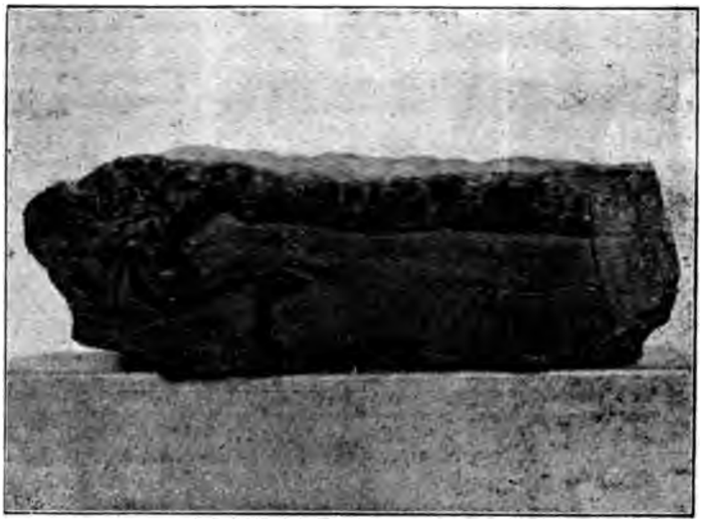
* Vertical Sections, Geol. Survey, sheet 22, No. 1.

of the Cotham or Landscape Marble. On breaking the stone, it presented the appearance shown in Fig. 102. This thin bed of stone occurs in impersistent layers, in the first exposure of the Lower Purbeck Marls north of Durlston Head, and the features it presents are of interest when studied in connection with the Landscape Marble of Cotham. They may serve to throw light on the formation of more or less nodular masses of stone. In the case of the Landscape Marble, I have been led to suggest [*] that the arborescent markings were produced by the disarrangement of dark and pale bands of calcareous mud, during the solidification of the stone, and that the mammillated surface was rucked up in the course of the process, when individual portions of the calcareous mud shrunk into isolated nodular masses."[†]

FIG. 102.



The same specimen as in FIG. 101, *cut to show internal structure.*

In dealing with other structures commonly met with in the Purbeck Limestones, Mr. Woodward writes that "curious trifid, vermiform, and fucoidal markings occur on some of the beds, especially in Durlston Bay; [‡] and large ripple-marked slabs, of which an example is preserved in the Museum of Practical Geology, occur in the Middle Purbeck Beds of the same locality. Ripple-marks have also been noticed in the Upper Purbeck Cypris Shales, of Mupe (Mewps) Bay, and I have noticed similar markings in the rocks of the Vale of Wardour.

"Granular beds, having an oolitic appearance, occur in the Lower Purbeck Beds at Ringstead, Portisham, and in the Vale of Wardour. Mr. Teall remarks that the Ringstead rock comprises mud-pellets, with or without thin coatings of radial (oolitic) carbonate of lime. Where two or more mud-pellets are in contact, there is no distinct line of demarcation, and there is no matrix.

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[*] *Geol. Mag.*, 1893, p. 110. *See also* Geol. Survey Memoir on the Lias of England and Wales, p. 30, and B. Thompson, *Quart. Journ. Geol. Soc.* vol. l., pp. 393, 409, &c., 1894.

[†] Jurassic Rocks (Geol. Survey Memoir), vol. v., p. 230.

[‡] T. R. Jones, *Quart. Journ. Geol. Soc.*, vol. xli., p. 323.

"Prof. Rupert Jones, who previously examined another specimen which I collected at Ringstead, found it to consist 'of a mass of small roundish granules and Cyprides (*Cypris purbeckensis*) coated more or less with calc-sinter, including also small tubes (*Serpulæ?*). This is comparable with a similar Purkeckian bed near Boulogne.' * . . .

Microscopic Structure.

"A granular limestone from Portisham, examined by Mr. Teall, was 'mainly composed of pellets which may contain traces of *Girvanella.* These pellets are often surrounded by a thin zone of oolitic character (concentric and radiate). The interspaces are mostly empty.'

"A granular limestone from the Lower Purbeck Beds, east of Lulworth Cove, examined by Mr. Teall, showed 'Mud pellets often taking the form of rice-grains. Sometimes where two or more are in contact they appear to blend. At other times one appears as if pressed into the other. The matrix is fine-grained, clear crystalline calcite.' [See also p. 85.]

"A brown shell-limestone from the 'Hard Cockle Beds' of the Lower Purbeck Beds at Mupe Bay, showed 'Sand-grains, organic fragments, oolitic grains, and more or less rounded pellets (showing *Girvanella*-structure ?) in a fine-grained crystalline matrix. Some of the fragments have a narrow coating of oolitic material, showing concentric and radiate structure.'"†

The cherts vary in their contents according to the horizon at which they occur. Thus a seam of dark chert in the tufa (Purbeck "Cap") surrounding one of the tree-stools in the cliff half a mile east of Lulworth Cove is of purely fresh-water origin. It contains *Valvata naticoides* in abundance and an occasional stem of *Chara*, but no sponge-spicules. It seems to have been originally cavernous like the calcareous tufa, but the cavities have all been filled up with chalcedony. A thin section shows that part of the silica has been deposited in the form of small globules, which are thought by Dr. Hinde to be analogous to the discoidal and globate forms of silica which occur in the sponge-beds of the Upper Greensand, except in being crystalline instead of colloidal. A chert in the Middle Purbeck division at Kingston on the other hand is made up almost entirely of the shells of *Corbula* sp. (not the form usually seen), and may be described as a silicified shell-marl. Others, like the specimen noted by Mr. E. T. Newton, ‡ contain stems of *Chara* in great abundance and beautifully preserved, together with *Ostracoda*, while lastly some of the cherts are sponge-beds, as shown by Dr. Hinde. §

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* *Quart. Journ. Geol. Soc.*, vol. xli., p. 326. See also *Proc. Geol. Assoc.*, vol, viii., p. 58; and Bull, *Soc. Géol. France*, ser. 3, vol. viii., p. 616.

† Jurassic Rocks, vol. v., p. 233.

‡ *Proc. Geol. Assoc.*, vol. xiv., p. 310 (1896).

§ Brit. Jurassic Sponges (*Pal. Soc.*), p. 212.

Subdivisions.

The Purbeck strata have been divided up into three arbitrary subdivisions, namely, the Upper Purbeck, fresh or brackish and characterised chiefly by *Paludina*, *Unio*, *Cyrena*; the Middle Purbeck, partly brackish and partly marine, the former containing *Cyrena*, *Hydrobia*, *Limnœa*, *Planorbis*, &c., and mammals, and the latter *Corbula*, *Pecten*, *Ostrea*, &c.; and the Lower Purbeck, which are chiefly fresh or brackish and enclose many insects in addition to the shells named above. In this lowest subdivision occurs also the well-known dirt-beds with the silicified cycadaceous trees embedded in calcareous tufa ("cap"). Remains of fishes occur in fair abundance throughout the group, and of saurian and turtles in its upper part. Casts in clay of crystals of rock-salt, and gypsum, a frequent accompaniment of lacustrine or estuarine deposits, are found in the Lower Purbeck marls and 'granular' limestones. Nodules of black chert occur at a few horizons, and a specimen obtained by Mr. J. T. Young* at Stair Cove was found by Dr. Hinde † to consist mainly of the spicules of *Spongilla purbeckensis*.

Brecciation.

In the Lower Purbeck subdivision there occurs that remarkable condition of the strata known as the "broken bands." The lower Purbeck limestones, which lie next above the tufaceous "cap," occasionally pass into a coarse breccia, the thickness of rock thus affected ranging from three to upwards of twenty feet. Where fully exposed, as in the cliff half a mile east of Lulworth Cove, the rock-bands can be seen to run normally for a distance, but then to tend to pucker up and break into separate blocks. In a few yards the continuity is lost, and though the blocks of the same band can be recognised at their proper horizon, they are completely separated from one another and placed at all angles. They are imbedded in a calcareous cement largely composed of smaller fragments of the "broken" limestones. No foreign material occurs. The "breaking up" not only dies away horizontally, but shades away more or less gradually upwards; it seems even here and there to eat its way upwards, involving strata in one place which are unbroken close by. The breccia thus formed, as band after band breaks up and contributes great blocks to the confused mass, forms a conspicuous feature in the cliffs from Mupe Bay to Durdle, but is nowhere better seen than east of Lulworth (Plate iii.). Notwithstanding the violent movements which the structure suggests the strata above and below are quite undisturbed. Similar brecciation of the Lower Purbeck limestones is observable near the Bill of Portland (pp. 116, 118), in the London Door Quarry, near Kingston, and elsewhere in the Isle of Purbeck.

Webster, who was the first to mention and speculate on the cause of this curious condition,‡ suggested that the abstraction of clay may have caused the superincumbent strata to fall in. Sedgwick and Murchison compared the structure to that which affects certain massive Devonian limestones underlain by slates.* When subjected to pressure the slates were moulded, while the limestones were bent, the part of the limestone being played in the present case by the tabular mass of Portland Stone. The Rev. O. Fisher, in 1854, gave an accurate account of the extent of the brecciation, and pointed out that near Lulworth above the tufa enclosing the trees "all the strata are broken up until we reach the cardium-bed . . . which is undisturbed. The disturbance appears to diminish in intensity as we approach this limit . . . A stratum of clay immediately beneath the cardium-bed dips down among the inequalities of the broken bands, and affords a level surface for the cardium-bed to repose upon." He concludes that the beds were solidified and then fractured before the cardium-bed was deposited, and suggests that their fracturing was due to their having been deposited over a mass of decaying trees and mosses, and having subsequently fallen in.† In 1887 Mr. H. B. Woodward recurred to the view that movements subsequent to the Purbeck period had caused the crushing,‡ and in 1895 enlarged upon this point.§ While admitting that the strata "were somewhat irregularly accumulated over the terrestrial surfaces and hummocky 'burrs'," and that a certain amount of dissolution of calcareous matter has taken place from the sandy limestones that form the mass of the strata, he remarks on the fact that the disturbances affect strata higher in some places than in others, and concludes that "this proves that the main features of the disturbances could not have been produced in Purbeck times, and that the shattering must have been caused during the tilting and shifting of the strata."

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* *Geol. Mag.* 1868, p. 220.

† British Jurassic Sponges (*Pal. Soc.*), p. 212.

‡ Englefield's Isle of Wight, pp. xix. and 173, and Plates,

It is certain that the "broken bands" are neither gash-breccias nor fault-rock in the ordinary sense of the terms; though, like the rest of the strata, they are occasionally displaced by faults, as at Durlston Head. On the contrary, the structure follows a stratigraphical horizon, and though it is more fully developed at Lulworth than elsewhere, it has been recognised from Durlston Head as far west as Portland, and even in the Vale of Wardour.‖ This wide extension of the phenomenon greatly strengthens Mr. Fisher's view that the brecciation was contemporaneous, that is, that it was produced previously to the deposition of the overlying unbroken beds rather than by dislocations of the strata during subsequent periods. The supposition that the strata fell in owing to the decay of a mass of vegetable matter beneath is supported by the unusual abundance of fossil trees at the locality where the brecciation is most intense; but, on the other hand, as Mr. Woodward remarks, where the great dirt-bed is so well shewn on Portland the "broken beds" though not absent are less conspicuous than those near Lulworth. The connection of the structure with the post-Cretaceous Isle of Purbeck disturbance is still less satisfactory, for even at Lulworth the Lower Purbeck strata show no exceptional disturbance due to that fault, while in some other localities where the "broken bands" occur they are not visibly affected at all.

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* *Trans. Geol. Soc.*, Ser. 2, vol. v., p. 655.

† *Trans. Camb. Phil. Soc.*, vol. ix., p. 566, 1855.

‡ Geology of England and Wales, 2nd Ed., p. 347.

§ The Jurassic Rocks of Britain (Memoir Geol. Survey), vol. v., pp. 247 to 249.

‖ According to Messrs. Andrews and Jukes-Browne, *Quart. Journ. Geol. Soc.*, vol. l., p. 50, 1894.

It should be borne in mind that the strata exhibiting this exceptional structure are themselves of an exceptional character. The massive Lower Purbeck limestones lying below the "broken bands" are mostly tufas, that is, amorphous deposits of carbonate of lime, and not sediments composed of organic *débris*. Such deposits assume the utmost irregularity at all times, but more especially would they do so when clothing a forest-grown land-surface with prostrate trunks such as we see at Lulworth. Moreover, carbonate of lime thus precipitated always encloses a vast number of vacuities, besides being more or less cavernous. These peculiarities seem frequently to have led to such deposits having been subsequently broken up before they were finally buried. Thus the similarly formed limestones, or "cornstones" of the Old Red Sandstone, are usually breccias or conglomerates of cornstone-fragments in a cornstone or sandy matrix. Brecciation also frequently accompanies the similar limestones of Triassic age. On the whole, therefore, the evidence seems to preponderate in favour of Mr. Fisher's view that the structure in the Purbeck rocks is contemporaneous, and due to the exceptional condition of those strata, while his suggestion that the collapse was due to the decay of the forest growth, supplemented by a consideration of the behaviour of tufas, offers the best explanation of the "broken bands" at present available. It is significant that the nearest approach to the "broken bands" in other formations occurs in connection with the Cromer Forest Bed. In that stratum Mr. Reid has observed a laminated clay broken into masses which stand at all angles, although the beds above and below are undisturbed. This "broken band" is about 3 feet thick and impersistent, but tends to reappear at nearly the same horizon. The strata above and below are estuarine laminated blue clays belonging to the Forest Bed series.

Formation of the tufas and forest-beds.

The Lower Purbeck strata consist in the main of well-bedded or laminated limestone, generally rich in Cyprids, and with partings of light-coloured shale or marl. The limestones predominate towards the lower part of the subdivision, and are more fully developed in the Weymouth than in the Swanage district. Among these Cyprid-beds, and interrupting them in their even deposition, lie the dirt-beds with the stumps and prostrate trunks of coniferous trees, each dirt-bed being overlain by a more or less continuous mass of calcareous tufa. The deposition of the tufa was most irregular, but was sometimes determined by the presence of the stumps and trunks of the trees, for not only does it invariably envelop them, but in one case at least it can be seen to have coated a stump at the same time that laminated Cyprid-limestone was forming all round at 2 or 3 feet distance (p. 111). The structureless tufa and the laminated limestone, therefore, may be regarded as having been contemporaneously formed, but the precipitation of the lime in the two rocks as having been brought about in a different manner. In the case of the tufa the precipitation was probably determined by the presence of masses of decaying wood. It is a common experience that twigs, leaves, and branches of moss, when placed in a "petrifying spring," are coated with tufa more rapidly than the pebbles in the bed of the stream, and even arrest carbonate of lime which would otherwise have passed away in solution. The rough surface of such objects may partly account of the precipitation of the lime, but it is more probable that their effect is due to their providing a suitable habitat for the growth of freshwater algæ, and that the deposition of the carbonate of lime is the result of the abstraction of carbonic acid from the solution by these organisms.[*] Such an effect would be especially marked in the shallow and perhaps stagnant water which submerged the forest-growth of the Purbeck land-surfaces, where every trunk or stump would give rise to a copious algous growth. The laminated limestones consist partly of the shells of Cyprids, but probably owe their origin principally to the action of low forms of vegetation. Though no plant-structure is now recognisable in the limestone, *Chara*, a fresh-water plant, which flourished both in purely fresh and slightly brackish water, is not uncommon in the chert-bands; the power of this plant to precipitate lime is well known. At the same time, mere exposure to the air is sufficient to cause the deposition of carbonate of lime from a saturated solution of the bicarbonate by allowing the escape of carbonic acid gas. Cave-deposits are usually formed in this way, and not improbably part of the matrix in which the Cyprids are imbedded was of a similar inorganic origin.

The woody material of the trees has generally been replaced by chalcedony, and the structure beautifully preserved. This fact, and the presence of occasional irregular seams of chert in the tufaceous envelope of the stumps, points to the deposition of silica and carbonate of lime having proceeded contemporaneously, though at the same time some of the chert can be proved by its contents to be altered limestone.

The upright trunks occasionally reach a height of 5 or 6 feet, but average about 3 feet, and therefore seldom penetrate the limestone overlying their tufaceous envelope. They were obviously much decayed, as well as broken off, before being encased, and the fact that so many rotted through at about the same height from the ground suggests their having been submerged to that depth in water. The prostrate trunks, on the other hand, attain a great length; one recorded by Fitton measured nearly 20 feet from the roots to the first bifurcation, and 23½ feet in all, its diameter at 2 feet from the extremity of the root being 18¾ inches in one direction and 12½ in the other. The largest seen by Fitton was 2 feet 10 inches in diameter.[*]

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[*] On this subject see F. Cohn. Die Algen des Karlsbader Sprudels, mit Rücksicht auf die Bildung des Sprudel Sinters: *Abhandl. der Schles. Gesell*, pt. 2 Nat., 1862, p. 35 and W. H. Weed, U.S. Geol. Survey, 9th Ann. Rep., 1887-88.

The tufaceous envelope generally domes over the head of the stumps, but sometimes leaves a conical hollow to mark the position of the stump within the mass (Plate II. and Fig. 128). A somewhat similar structure was observed by Prof. Henslow in the rare case of a stump protruding from the tufa ("burr") into the overlying limestone ("Aish"). The stump was surrounded by two circular ridges in the surface of the tufa, with intermediate circular depressions.[†] The ridges were attributed by Buckland and De la Beche to ripples having broken against the protruding stump. The structure, however, may have been due to the action of filamentous freshwater *algæ* growing from the stump and radiating from it as a centre.

As already mentioned the erect trees are in the position in which they grew, and occasionally their roots have been traced for some distance in the dirt-bed, but not into the "cap" below. Fitton writes that "in one instance a prolonged branch of the root had evidently been bent out of its course by meeting the Cap, and was continued along its surface for several inches; the quarrymen said that such cases were not uncommon, and that the roots sometimes ran along the top to a much greater distance, but never penetrated the Cap itself."[‡] The cap on Portland Island, however, frequently contains casts of prostrate trunks or branches (pp. 115, 116), the wreckage of trees which were rooted in the dirt-bed below.

In addition to these coniferous trees the Lower Purbeck strata contain abundantly the remains of Cycads, ranging from 9 inches to a foot in diameter, and from 9 to 10 inches in height. They are found not only in the upper dirt-bed of Portland, but also in the strata above, and are popularly known as "fossil crows' nests." In 1895 the largest specimen yet recorded was discovered by Mr. A. M. Wallis, lying horizontally in a bed of shaly clay about 14 feet above the upper dirt-bed, in a quarry close to St. George's Church, on the west side of the old Portland Wide Street. It measures nearly 4 feet in length, and about 3½ feet in circumference at the broadest part, and has been described by Mr. A. C. Seward under the name of *Cycadeoidea gigantea*, sp. nov.[§]

The upper portion of the Lower Purbecks consists for the most part of alternations of shale and thin limestone. The occasional presence of gypsum and pseudomorphs of rock-salt points to the strata having originated in lagoons or estuaries partly, if not wholly, land-locked, and this conclusion is supported by the nature of the fauna, which is remarkably poor in number of

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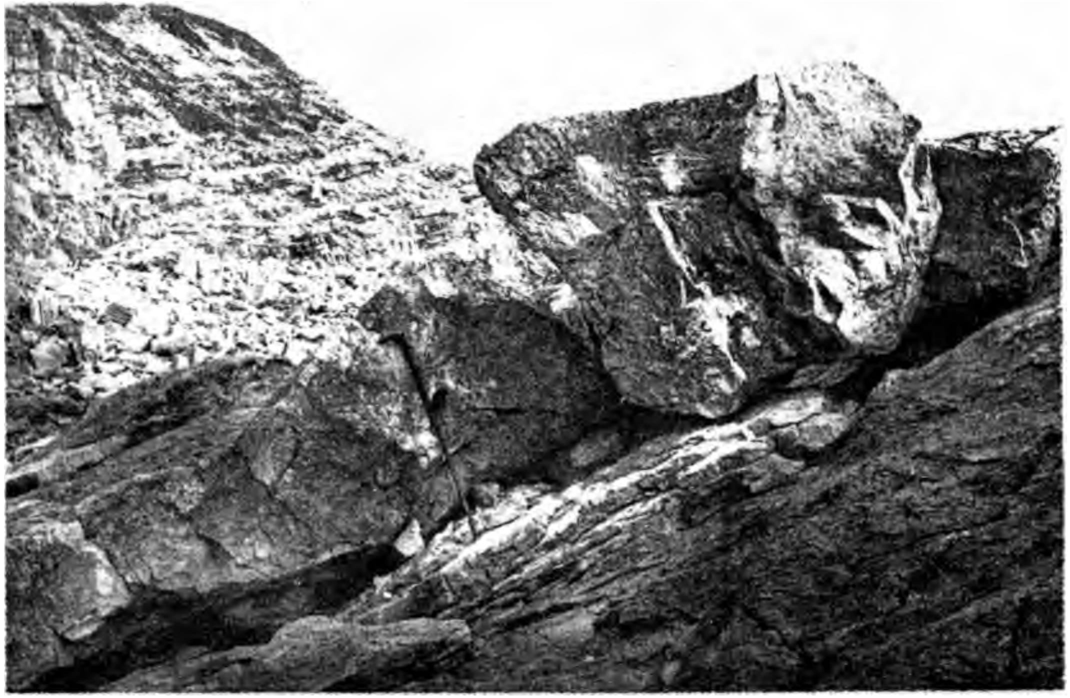
[*] Strata below the Chalk, pp. 221, 222.

[†] Buckland and De la Beche, *Trans. Geol. Soc.*, Ser. 2, vol. iv., pp. 16-17 and Figure. The figure is reproduced by Damon, *Geology of Weymouth*, 2nd. Ed, p. 115. See also drawings by Webster, *ib.* vol. ii. Plate vi. Figs. 3 and 4.

[‡] *Strata below the Chalk*, p. 221.

[§] *Quart. Journ. Geol. Soc.*, vol. l., p. 22 (1897).

Plate II.



PURBECK DIRT BED AND FOSSIL TREE NEAR LULWORTH.

9620.R 97

species, and though for the most part freshwater, consists of such forms as could survive an occasional invasion of salt water.

The pseudomorphs occur in a limestone composed principally of pellets of carbonate of lime with or without concentric oolitic growth. In a specimen from the cliff east of Lulworth the pellets are cylindrical and totally devoid of the characteristic oolitic structure. This fact, taken in connection with their uniformity in size and shape, suggests that they are the remains of organisms, but the indefiniteness of their structure prevents their determination. In shape they resemble the articulations of some sea-weeds, such as the Coralline, *Jania rubens*, or the granules described by M. Munier-Chalmas in the Eocene as the articulation of the branches of *Penicillus*. The larger cells of some *Characeæ* might yield internal casts of similar form. That limestones formed by algæ may loose all structure is well-known.*

Physical Conditions.

The abrupt change from the marine fauna which abounds in the very topmost layer of the Portland Stone to the scanty freshwater organisms of the Purbeck strata points to a more complete change in the physical condition of the region than would have been suspected from purely stratigraphical evidence. For not only are the two formations conformable, but the limestones composing them are indistinguishable at a short distance; nor as far as Dorset is concerned is there evidence of erosion of the top of the Portland, such as has been noticed locally in Wiltshire and elsewhere.† Yet the marine conditions which had prevailed uninterruptedly through much of the Secondary Period now came abruptly to a close, and were not renewed until the era of the Lower Greensand. The Purbeck and Wealden strata may be regarded as locally filling a gap which in their absence would have been marked by sub-aerial denudation, for that the Portland Stone was raised above the level of the sea is proved by the land-surfaces described above. That they were raised without fracture or folding is shown by their perfect parallelism with the overlying Purbeck, and though they soon sank again, the depression was insufficient to counterbalance the growth of sediment, except at those intervals when an estuarine fauna appears among the otherwise freshwater Purbeck-Wealden. The land-surface, therefore, which came into existence, must have been flat and featureless, raised but very little above sea-level and composed wholly, in the South of England, of limestone. To such abnormal conditions seems to have been due the alternation of forest and lagoon, and the formation of the dirt-beds and tufas of the Lower Purbeck strata.

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* J. Walther, *Zeitsch Geol. Ges.*, vol. xxxvii., p. 329, 1885. See also a valuable summary by A. C. Seward, *Science Progress*, vol. ii., p. 10, 1894.

† Jurassic Memoir (Geol. Surv. Memoir), vol. v., p. 277, where also reference will be found to the writings of the Rev. P. B. Brodie, Prof. Blake, and others, on the subject.

Organic Remains.

By H. B. Woodward, F.R.S. (Jurassic Rocks of Great Britain, vol. v., pp. 236-238).

The Purbeck Beds have yielded an exceedingly varied series of fossils. Perhaps of the highest interest are the Mammals, which at present have been obtained only from the base of the Middle Purbeck Beds of Durlston Bay—in a thin earthy or "Dirt" layer—in the very bed in which Forbes suggested they might be found.*

PURBECK MAMMALS.

From the Guide to the Department of Geology, British Museum, Part I. 1890.

FIG. 103.

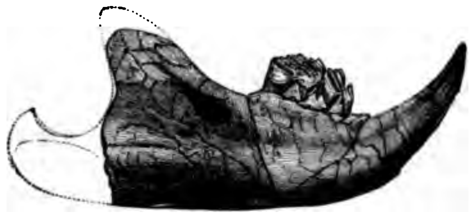

FIG. 104.

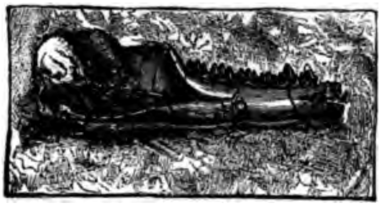

FIG. 105.

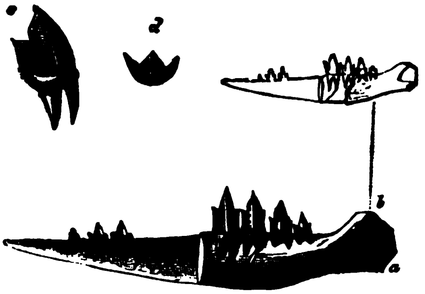

FIG. 103. Plagiaulax Becklesi, *Falc.*, 2.
Middle Purbeck, Swanage.
„ 104. Triconodon mordax, *Owen.*
Middle Purbeck, Swanage.
Lower jaw and teeth.
„ 105. Spalacotherium tricuspidens, *Owen*
Middle Purbeck, Swanage.
a. b. Imperfect left ramus of mandible
c. d. Lateral and upper views of a molar tooth.

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* Geikie, Memoir of Edward Forbes, 1861, pp. 460, 461.

We are indebted to W. R. Brodie, of Swanage, and Charles Willcox, for the discovery of *Spalacotherium* in 1854, and two years later S. H. Beckles obtained a number of additional forms, including *Plagiaulax*. These fossils are far from abundant, and long and patient search may be unrewarded. In 1880, after 10 days' search, Mr. E. W. Willett obtained one specimen of *Triconodon mordax*.

At least 12 genera and 22 species of Mammals have been described. They are Marsupials, insectivorous and herbivorous in habits, and are of diminutive size. The principal genera, such as *Spalacotherium, Triconodon*, and *Plagiaulax*, have been described by Sir Richard Owen and Dr. H. Falconer.

Until recently no such remains had been found in the Wealden formation, and it is therefore interesting to note that a specimen described by Mr. A. Smith Woodward as *Plagiaulax Dawsoni*, and another, described by Mr. Lydekker as *Bolodon*, have been obtained from the Wadhurst Clay, near Hastings.*

PURBECK MOLLUSCA.

FIG. 106.

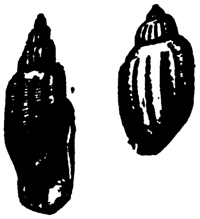

FIG. 109.

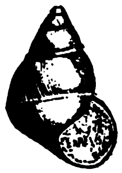

FIG. 107

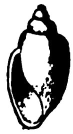

FIG. 108.

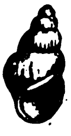

FIG. 113.

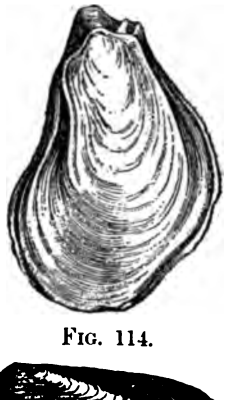

FIG. 111.

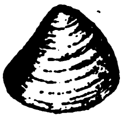

FIG. 110.

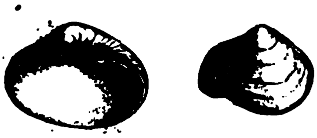

FIG. 115

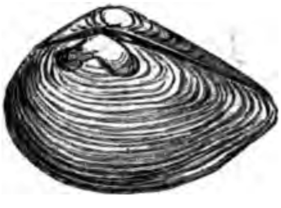

FIG. 112.

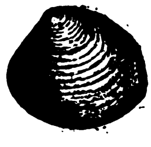

FIG. 114.

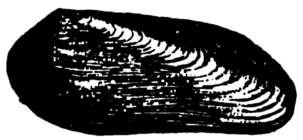

FIG. 106. Melanopsis harpæformis, *Dunk.*
„ 107. Physa Bristovii, *Forbes.*
„ 108. Paludina elongata, *Sow.*
„ 109. —— carinifera, *Sow.* 2.
„ 110. Corbula alata, *J. Sow.*

FIG. 111. Corbula, sp. 2.
„ 112. Cyrena media, *J. Sow.*
„ 113. Ostrea distorta, *J. Sow.*
„ 114. Unio, sp.
„ 115. —— valdensis, *Mant.* ⅔.

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* *Proc. Zool. Soc.*, 1891, p. 585; and *Quart. Journ. Geol. Soc.*, vol. xlix., p. 21.

PURBECK FOSSILS.

FIG. 116.

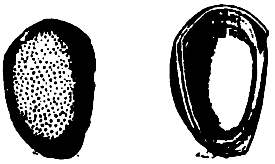

FIG. 117

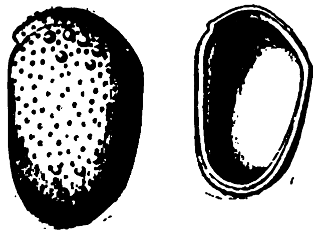

FIG. 118.

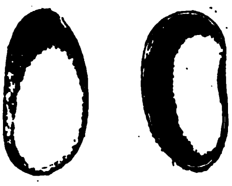

FIG. 119.

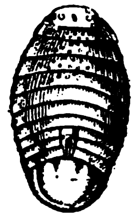

FIG. 121.

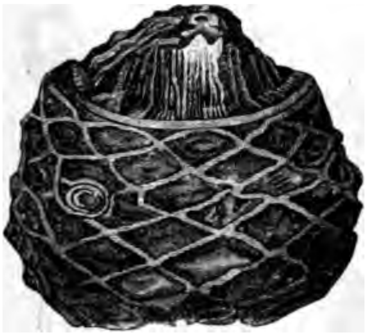

FIG. 120.

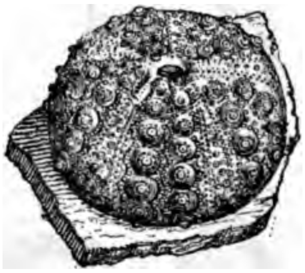

FIG. 116. Cypridea punctata, *Forbes*. $\frac{20}{1}$.
„ 117. —— granulosa, *Sow*. $\frac{20}{1}$.
„ 118. Cypris purbeckensis, *Forbes*. $\frac{20}{1}$.
„ 119. Archæoniscus Brodiei, *M. Edw.*
„ 120. Hemicidaris purbeckensis, *Forbes*. $\frac{1}{2}$.
„ 121. Mantellia (Cycadeoidea) microphylla. *Buckl.* $\frac{1}{3}$.

No traces of Birds have as yet been found. Remains of Frogs were recorded from the Purbeck Beds of Swindon, by Charles Moore,* but their occurrence is considered exceedingly doubtful by Mr. E. T. Newton.

Among the fossils from the Purbeck Beds the Saurian remains are important. The Dinosaurs include *Iguanodon* and *Nuthetes;* then we have the "Swanage Crocodile," *Goniopholis crassidens*, and the dwarf Crocodiles known as *Nannosuchus* and *Theriosuchus*. Owen estimates the average length of a mature *Theriosuchus* at eighteen inches. Turtles have been obtained mostly from the quarrymen, as they occur in the stone-beds: they include *Tretosternum*, *Pleurosternum concinnum*, *P. Bullocki*, and *Chelone obovata*, some fine specimens of which are preserved in the museum at Corfe Castle. The Fishes include *Asteracanthus verrucosus*, *Caturus*, *Coccolepis*, *Hybodus*, *Lepidotus*, *Macrosemius*, *Ophiopsis*, and *Pleuropholis*, and they are mostly found in the stone-beds worked at the quarries. Specimens occur at various horizons in the Purbeck Beds, and some of the best preserved examples have been obtained from the neighbourhood of Teffont Evias, in the Vale of Wardour.

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* *Proc. Cotteswold Club*, vol. ii., p. 192; and *Proc. Geol. Assoc.*, vol. iv., p. 544

It was the intention of Edward Forbes to publish an account of the Invertebrata of the Purbeck Beds of Dorsetshire; and he had assigned names to a number of new species of Mollusca, which he was the first to discover.* Some of these have been figured in Lowry's Chart of Characteristic British Fossils, and others in works published on the Continent. They all belong to living genera, and taken by themselves, possess a Tertiary or even recent aspect.

Reference has already been made to the principal genera of Mollusca found in the Purbeck Beds, but it may be mentioned that Mr. Carruthers has described, under the name *Teudopsis Brodiei*, a cuttle-bone from these strata in Dorset.†

Insects are represented very fully by remains of Coleoptera, Orthoptera, Diptera, Neuroptera, and Hemiptera. To the various remains very numerous names were applied by Prof. Westwood,‡ and for our knowledge of these Insects we are chiefly indebted to the Rev. P. B. Brodie. There were Butterflies, Beetles, Dragon-flies, Locusts, Grasshoppers, Ants, and the earliest known Aphides; forms that are considered to indicate temperate conditions.

At Durlston the Insect-remains occur most abundantly in the Lower Purbeck Beds, elsewhere they are found in Middle Purbeck strata.

Among Crustacea, the Isopod *Archæoniscus* occurs in profusion in the Middle Purbeck Beds in the Vale of Wardour. It has been found, however, in the Lower Purbeck Beds of Wiltshire and Dorset.

In 1850 Edward Forbes named eight species of Ostracoda ("Cyprides") from the Purbeck Beds of Dorsetshire, but unfortunately he never described them.§ Figures of these species, reduced from diagrams used by Forbes in his lectures at the Royal School of Mines, were afterwards published by Lyell.|| It has not, in every case, been possible to identify the specimens upon which the names of these species were based, while some doubts have arisen concerning the particular horizons from which they were obtained. These difficulties have been pointed out by Prof. T. Rupert Jones, and more recently he has given a full

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* Some figures of Purbeck fossils will be found in the works of Fitton, *Trans. Geol. Soc.*, ser. 2, vol. iv., Plates XXI. and XXII.; Mantell's "Geological Excursions round the Isle of Wight," ed. 3; and Damon's "Geology of Weymouth," &c., ed. 3, 1888 (supplement).

† *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 448.

‡ *Ibid.*, vol. x., p. 391.

§ *Rep. Brit. Assoc.* for 1850, pp. 79-81.

|| Manual of Geology, edit. 3, p. 231; and Elements of Geology, edit. 6, 1865.

account of the subject, with a revision of the names and descriptions of new species.[*] These are for the most part freshwater forms, but the genus *Cythere* is marine, and *Candona* is said to be estuarine.

Among the Ostracods it is found that *Cypris purbeckensis*, *Candona ansata*, and *C. bononiensis* are most abundant and characteristic in the Lower Purbeck Beds; *Cypridea granulosa* in the Middle Purbeck; and *C. punctata* in the Upper Purbeck. Their particular range was not, however, restricted, and it is interesting to note that Prof. Jones has recorded *Cypris purbeckensis*, and a variety of *Cypridea tuberculata* from the Upper Cretaceous strata of Wyoming, in North America.[†]

Here and there at various horizons in the Middle and Lower Purbeck Beds a number of "Dirt Beds" occur. The name has been applied to layers of carbonaceous clay or shale, but it originated in Portland Island, where the Great Dirt Bed which occurs near the base of the Lower Purbeck Beds is especially noted for the silicified remains of Cycads and Coniferous trees which it has yielded. There great "Burrs" of siliceous and calcareous (tufaceous) material have been accumulated around the old tree stumps, an example of which seen in the cliffs east of Lulworth Cove is shown in Fig. 128, p. 102, and another at Portisham is shown in Fig. 130, p. 111.

A bed yielding similar more or less silicified plant-remains has been observed near Lulworth and eastwards to Gad Cliff;[‡] and there are traces of Burrs to the east of Dancing Ledge as observed by Mr. Strahan and myself in 1893.

Chara was found in the cherty freshwater band of the Middle Purbeck Beds by Edward Forbes.[§] (See also p. 79.)

The following may be included as among the more common and characteristic fossils of the Purbeck Strata:—

Melanopsis harpæformis (Fig. 106).
Paludina carinifera (Fig. 109).
—— elongata (Fig. 108).
Physa Bristovii (Fig. 107).
Corbula alata (Fig. 110).
Cyrena (Cyclas) media (Fig. 112).
—— (——) parva.
Modiola.
Ostrea distorta (Fig. 113).
Unio compressus.
Unio valdensis (Fig. 115).
Archæoniscus Brodiei (Fig. 119).
Candona ansata.
—— bononiensis.
Cypridea granulosa (Fig. 117).
—— punctata (Fig. 116).
Cypris purbeckensis (Fig. 118).
Hemicidaris purbeckensis (Fig. 120).
Mantellia microphylla (Fig. 121).
—— nidiformis.

H. B. W.

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[*] *Geol. Mag.*, 1878, p. 105; and *Quart. Journ. Geol. Soc.*, vol. xli., p. 311.

[†] *Ibid.*, 1893, p. 386.

[‡] See Fitton, *Trans. Geol. Soc.*, ser. 2, vol. iv., pp. 220, 223; see also Buckland and De la Beche, *ibid.*, p. 14.

[§] See also E. Wethered, *Proc. Cotteswold Club*, vol. x., p. 101.

CHAPTER VII.—UPPER OOLITIC ROCKS (*continued*).

PURBECK BEDS (*continued*).—LOCAL DETAILS.

Swanage and Durlston Bay. (Plate XI.)

(Vertical Sections of the Geological Survey, Sheet 22.)

The junction of the Purbeck and Wealden formations is hidden at Swanage by the alluvial flat of a small stream, but the Upper Purbeck Marble beds have been seen in or near the main street west of St. Mary's Church. Thence the outcrop follows the street eastwards, and runs into the sea at the pier, while the "broken shell limestone" forms the neighbouring shore. The beds undulate considerably, but dip generally northwards, at angles ranging up to 18°, so as to expose broad, sloping bedding-planes to the waves. A curious structure, noticed by Fitton more than seventy years ago, is still conspicuous. He says "the surface . . . . . was depressed in some places into nearly circular pits or cavities, from 4 to 7 feet in diameter and about a foot deep in the middle, as if the beds had been forced in by a violent blow, the depressed surface being divided by irregular but nearly consecutive cracks, which were filled with white sparry carbonate of lime. Three of these depressions are visible; two of them about 6 feet apart, one of which was 7½ feet, the other about 4½ in diameter at the outer edge. A third, about 10 paces to the west of these, was of smaller dimensions."* The depressions are due apparently to hollows having been formed beneath the limestone, and to its having collapsed after consolidation, but it is not possible to see what caused the formation of the hollows. Near the Coastguard Station the Marble beds form the cliff, but both they and the beds beneath them are better seen at Peveril Point, where the coast crosses the strike of a number of small folds at right angles. The strata lie in a sharp syncline, within which are still sharper minor folds. The "broken-shell limestone," about 10 feet thick, and made up of fragments of *Cyrena*, with *Unio*, *Paludina*, and remains of fishes and turtles, crops out at the foot of the cliff, and forms the northernmost of the reefs which extend eastwards from the point. It dips sharply southwards, but rises again about 70 yards further south, and then runs steadily up the top of the cliff. The space between these two crops is occupied by the much-squeezed Upper Purbeck *Unio-* and *Paludina*-beds. The "Unio Beds" of Bristow's section lie next above the broken-shell limestone, but the Unio is more conspicuous a few feet higher up in the series (No. 12 of the Section, Fig. 122). Above this, again, two beds of limestone, the upper one blue, and the lower red, but both crowded with

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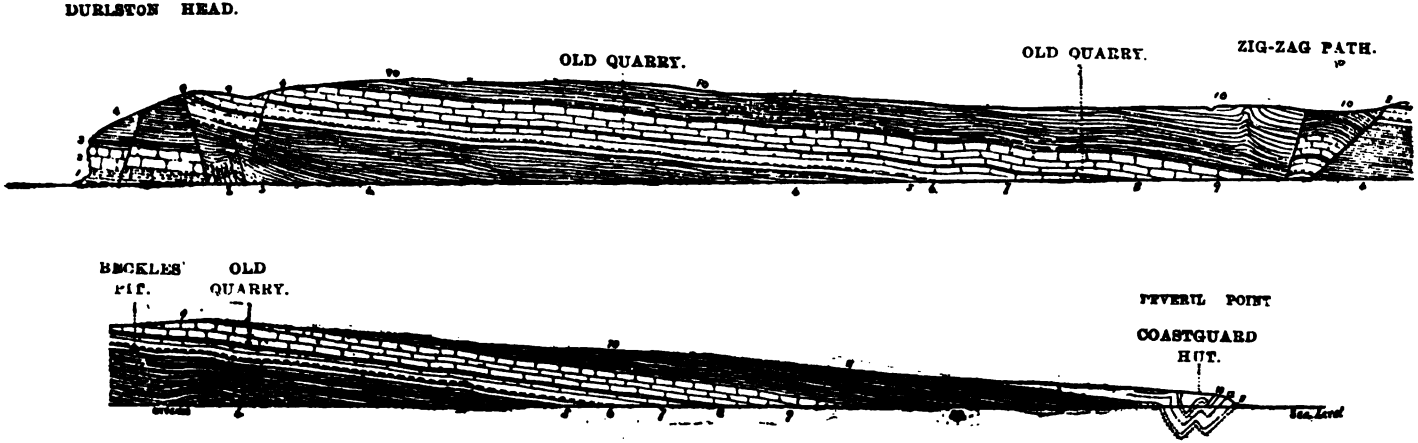
* ***Strata below the Chalk*, p. 209. Footnote.**

FIG. 122.

Section from Durlston Head northwards to Peveril Point, Swanage.

Distance one mile.



Lower Purbeck Beds. { 4. Marls with gypsum.
3. Caps and Broken Beds.

Upper Portland Beds. { 2. Freestone.
1. Chert Beds.

Upper Purbeck Beds. { 13. Two Marble Beds.
12. Unio Beds.
11. Broken Shell Limestone or Burr.

Middle Purbeck Beds. { 10. Corbula and Beef Beds.
9. Stone Beds.
8. Cinder Bed.
7. Stone Beds.
6. Black Shale with Flint Bed, 3 ft. 10 ins., above.
5. Mammal Bed.

Paludina carinifera, can be readily identified; they are the well-known Purbeck Marble, which has been in use for several centuries for the internal decorative work of cathedrals, and has been quarried for that purpose as far west as Kingston. Both in the Paludina marble and the Unio limestones the interior of the shells is often filled with a soft, earthy, greenish mineral, insoluble in dilute hydrochloric acid, and somewhat resembling glauconite—a mineral which, however, has hitherto been found only in marine sediments.

The limestones mentioned above are interstratified with shales containing Cyprids and layers of fibrous carbonate of lime locally known as "beef." The crystals are arranged at right angles to the layer in which they occur. They are "usually found shooting upwards from a band of perished bivalves, and appear due to a change in the condition of the shells on which they rest. The connection of these bands of 'beef' with deposits of bivalve shells is most strikingly seen in the neighbourhood of Osmington."* With the carbonate of lime are associated sulphate of lime in the form of selenite and sulphate of alumina in the form of alum, all being the result of recent chemical action in the shales.

The "Chief Beef Beds," however, of Bristow's Section lie immediately below the "broken-shell limestone." They consist of light and dark shales, sometimes finely laminated, with numerous crushed specimens of *Cyrena* and *Cyprides;* the total thickness being about 34 feet.

The *Corbula* Beds, which underlie the Beef Beds, take their name from the abundance of that shell, but contain also *Melania, Pecten, Cardium* (?) and other fossils confirming their marine origin. They contain more limestone than the Beef Beds, but are much split up by shales which contain alum and beef and present no essential difference from those above. "Near the top of the Corbula Beds there is a prominent band of broken-shell limestone with yellow sandy seams, and overlying this is a layer marked [in Bristow's Section] Toad's Eye Limestone, which contains irregular seams of indurated marl, and has curious tridactyl and vermiform markings on its surface."†

The upper building-stones, like those at a lower horizon, have in places been quarried in the cliffs, where old excavations and tunnels remain to mark the spots (Jurassic Memoir, vol. v., p. 252), but they are more extensively worked to the south-west of Swanage. Measuring from the White Roach to the top of the Cinder Bed, we find in this group about 51 feet of alternations of slabby limestone with shale-partings. Remains of fishes and turtles occur in several of the beds, while in others are found Cyprides, *Cyrena, Paludina* and oysters, together with plant-remains, the whole suggesting brackish-water estuarine conditions. *Macrorhynchus* occurs in the Downs Vein at the base of the group, and *Archæoniscus* in a shale band 23 feet higher up.

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* Fisher: On the Purbeck Strata of Dorsetshire. *Trans. Cambridge Phil Soc.*, vol. ix., part 4 (1855).

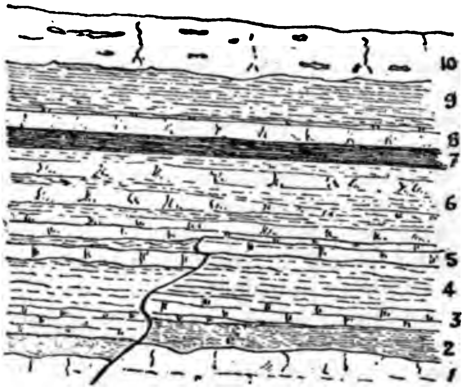
† Prof. T. R. Jones, *Quart. Journ. Geol. Soc.*, vol. xli., p. 323.

This group rests upon the Cinder Bed, the most conspicuous and constant band in the Purbeck series. It is made up almost entirely of a compacted mass of the shells of *Ostrea distorta*, but contains also other marine shells. In the upper part there are scarcely any shells except that oyster, but "in the middle portion is a band not above a foot thick which contains the *Hemicidaris purbeckensis* and its spines, with *Serpulæ* mingled with the oysters. The lower portion affords another species of oyster, broader than the *O. distorta*, and a *Cardium*."* Bristow records also *Perna* and *Trigonia*.

Beneath the Cinder Bed we again encounter a freshwater fauna, in which are included *Cypris*, *Cyrena*, *Corbula*, and *Melania*, together with the remains of insects, fishes, turtles, and the reptile *Nuthetes destructor*. The limestone next below the Cinder has been quarried under the name of "Feather Bed," while sixteen feet below the same horizon there occurs an easily recognised white limestone 3 feet thick with black chert-nodules. This "Flint Bed" contains *Paludina*, *Valvata*, *Physa*, *Planorbis* and *Cyrena* according to Bristow. Four feet below it a black carbonaceous shale, 10 inches thick, and containing insects and fishes, is readily identified, and serves as a guide to the less conspicuous "mammal bed," which lies 10 feet lower down again.

FIG. 123.

Junction of Lower and Middle Purbeck Beds, Durlston Bay
(H. B .Woodward).



		Ft.	In.
Middle Purbeck.	10. Flint bed	3	0
	9. Shale and marl	2	8
	8. Marl with thin limestone on top	1	2
	7. Black shale	1	0
	6. Shales and marls	5	0
	5. Hard limestone	1	0
	4. Soft marls	2	6
	3. Hard marl and limestone	1	9
	2. Grey earthy bed with Mammals	1	0
Lower Purbeck.	1. Hard marl.		

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* Fisher, *op. cit.*

The Mammal bed, which has been selected as the base of the Middle Purbeck division, is a brown carbonaceous earthy layer or "dirt bed," with occasional chert, filling inequalities of the bed below. Its interesting contents have already been referred to (p. 85). Most of the specimens were obtained by Mr. Beckles in a quarry which he opened for the special purpose of searching this band near the top of the cliff, and a few yards north of the Refreshment house (Fig. 122).

The Lower Purbeck strata of Durlston Bay consist for the most part of pale clays with irregular masses of gypsum, but include also some hard tufas at their base, at Durlston Head. In the upper part, though probably not marine, they are of salt-water origin, for they contain casts of crystals of rock-salt, the cavities being filled with carbonate of lime, with a trace of sulphate of baryta, according to Mr. Fisher. Fluoride of calcium seems also to be present in the rock, according to the same observer, the whole suggesting to him that the stone formed the muddy surface of a saltern, subject at times to be dried slowly. It is interesting to note that in these strata the shells so common at other horizons become extremely scarce, while on the other hand insect-remains were washed or blown into the brine in abundance. A section of the insect-beds given by Mr. Fisher shews a succession of conditions of the ancient surface—"The clubs of the antennæ of large beetles occur, with segments and other portions of the bodies, but the most abundant remains are elytra and wings. All the orders are represented." These insect-beds, as measured by Mr. Fisher, are 15 feet thick; they commence 14 feet below the Mammal bed, and 15 inches below a blue marl with *Serpula*.

Forty-five feet below them, and below the large masses of gypsum which were formerly worked here for making plaster-of-Paris, there is a cream-coloured marly limestone also "containing insects, associated with Cardia and Hydrobia. It was from this bed (116 of Mr. Austin's section) that the very beautifully preserved hemipterous insect in the Woodwardian Museum was obtained. This is the lower insect-bed of the Lower Purbecks, but elytra and small wings associated with vegetable matter continue to occur occasionally wherever the strata are of a texture favourable to their preservation. The Archæoniscus has been found in this last-mentioned stratum." (Fisher, *op. cit.*)

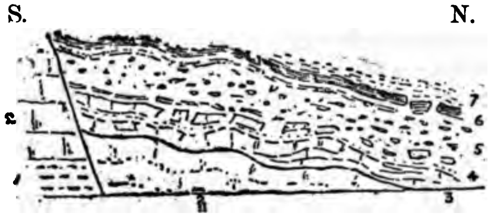
The continuity of the section in Durlston is broken by a large double fault at the zigzag path which leads up to the Refreshment room. The two parts of the fault almost meet at the foot of the cliff, but diverge upwards; the northernmost throws the Cinder Bed from the top nearly to the bottom of the cliff, the second throws it some few feet below the beach, from beneath which it rises again about 180 yards further on. For a time, therefore, we cross over the same strata we have already seen on the north side of the fault, keeping on the Corbula Beds if we follow the path along the cliff, but crossing the Cinder, Mammal, and Lower Purbeck strata in succession if we keep to the beach. The strata below the lower Insect-bed consist of clays and

Cypris-shales, with a band of olive-brown mudstone in the lower part, which contains *Archæoniscus*. These rest upon a breccia, composed of fragments of Cyprid-limestone with a few fragments of chert cemented together, an example of the brecciation which has been already described as so often affecting this part of the Purbeck series.

At Durlston Head, however, the complication is increased by faults indubitably of post-Purbeck age. The first of these we can prove by the fact that the Cinder Bed in the upper part of the cliff is thrown down southwards below Durlston Castle, though we cannot detect it in the soft clays at the foot of the cliff. The second is a downthrow north of about 80 feet, and can be found in tracing the junction of the Purbeck and Portland rocks round the headland. Between the two are seven or eight small steps, shifting the Purbeck base again and again, and giving a false appearance of unconformity between the two formations. The lowest Purbeck rocks, known as the Soft and Hard Caps, are irregularly laminated brown tufaceous limestones. A conspicuous parting separates the two caps, and perhaps represents the dirt-bed of the coast further west. A basement dirt-bed 3 inches thick separates the Purbeck and Portland stones.

FIG. 124.

Section at Durlston Head (H. B. Woodward).



7. Cypris Shales.
6. Limestones and Shales.
5. Broken Beds.
4. Soft Cap.
3. Hard Cap.
2. Portland freestone.
1. Portland cherty limestone.

According to Bristow's measurements (Vertical Sections, Sheet 22) the thickness of the Upper Purbeck is here 60 feet 7 inches, of the Middle Purbeck 166 feet 9 inches, and of the Lower Purbeck 169 feet 5 inches, giving a total of 396 feet 9 inches.

Durlston to St. Alban's Head.

From Durlston Head westwards the Lower Purbeck rocks generally form the brow of a dangerous cliff, but the Cinder Bed can be easily traced through a number of old quarries from one to two hundred yards inland. About 300 yards north of these the Cinder Bed crops out again, though it should be there far underground, the repetition of the outcrop being accounted for by the southerly downthrow mentioned above. The northerly downthrow of Durlston Head cuts the crop of the Cinder Bed north of the Lighthouse, and intersects the cliff 1,050 yards further west; it has diminished, however, to 25 feet. Just beyond it the following section is easy of access:—

One mile west of Anvil Point.

	FEET.
Waving bands of laminated limestone and shale, slightly contorted	5 to 6
Brown bituminous and cellular limestone (tufa), with chert on top	1 to 2
Dirt-bed—a layer of white sand and calcite, with seams of brown limestone	½
Portland Stone—fine-grained limestone of marly texture—*Lucina.*	

Near this point characteristic brecciation of the Lower Purbeck limestones develops suddenly for about 300 yards. The brecciation affects about 20 feet of strata, and extends up into the waving and laminated limestone of the above section. The tufa below it presents rounded protuberances resembling the tree-bosses of Lulworth (p. 102). Half an inch of brown earth or "dirt" separates the tufa from the Portland Stone. The dirt bed is accessible also near Seacombe up the Seacombe Valley, but is better exposed up the west branch of Winspit Bottom, where cellular tufa 2 to 2½ feet thick is separated by six inches of limestone-breccia from the Portland Stone.* Another convenient section occurs in the edge of the quarries 150 yards south of the chapel on St. Alban's Head, where a thin skin of Purbeck caps overspreads the Portland Stone for some distance.

Worbarrow.

The next coast-section of the Purbeck rocks occurs at Worbarrow. The base of the formation runs along the precipitous part of Gad Cliff from 6 to 40 feet below the brow, and then descends to a cove east of the Tout,† known as Pondfield, where it and the beds above it as far as the Cinder Bed are easily accessible.

The following section was noted in the west side of the cove:—

Pondfield, Worbarrow.

		FEET.
Lower Purbeck.	Broken bands, about	15
	ditto rubbly, fragments small	2
	Tufaceous limestone, the cavities lined with crystals of quartz, and the residue from hydrochloric acid consisting largely of doubly terminated crystals of that mineral	1 to 2
	Creamy laminated and wavy limestone	2
	Hard brown tufaceous limestone	½ to 1
	Inconstant dirt-bed	0 to 1
	Creamy laminated limestone	5
Portland Stone		

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* Lynchets, or old cultivation-terraces, are especially conspicuous on some of the hill-sides near Worth. Such terraces are partly due to the downwashing of the soil having been artificially checked. On the Isle of Portland land is still cultivated in long strips from 10 to 20 yards in width, and known as "lawns." This seems to be a consequence of what Hutchins refers to as the ancient tenure of gavelkind, the lands of the father being at his death equally divided among his sons or next of kin.

† The name Tout is applied to several conspicuous points in this part of England, and is probably derived from the old English *toten*, to look out, or spy.

The tufaceous limestone with quartz-crystals mentioned in this section has been examined by Mr. W. W. Watts, who furnishes the following note upon it :—

E. 2844. This is a limestone full of crystalline quartz. The bulk of the quartz occurs in the cavities, standing out in crystals from the sides, but many crystals occur completely embedded in the limestone. They are often perfect in shape, giving symmetrical basal sections or longitudinal sections showing prism and pyramid faces. It is quite obvious that they have been formed *in situ*. They contain no trace of any original grit-grains

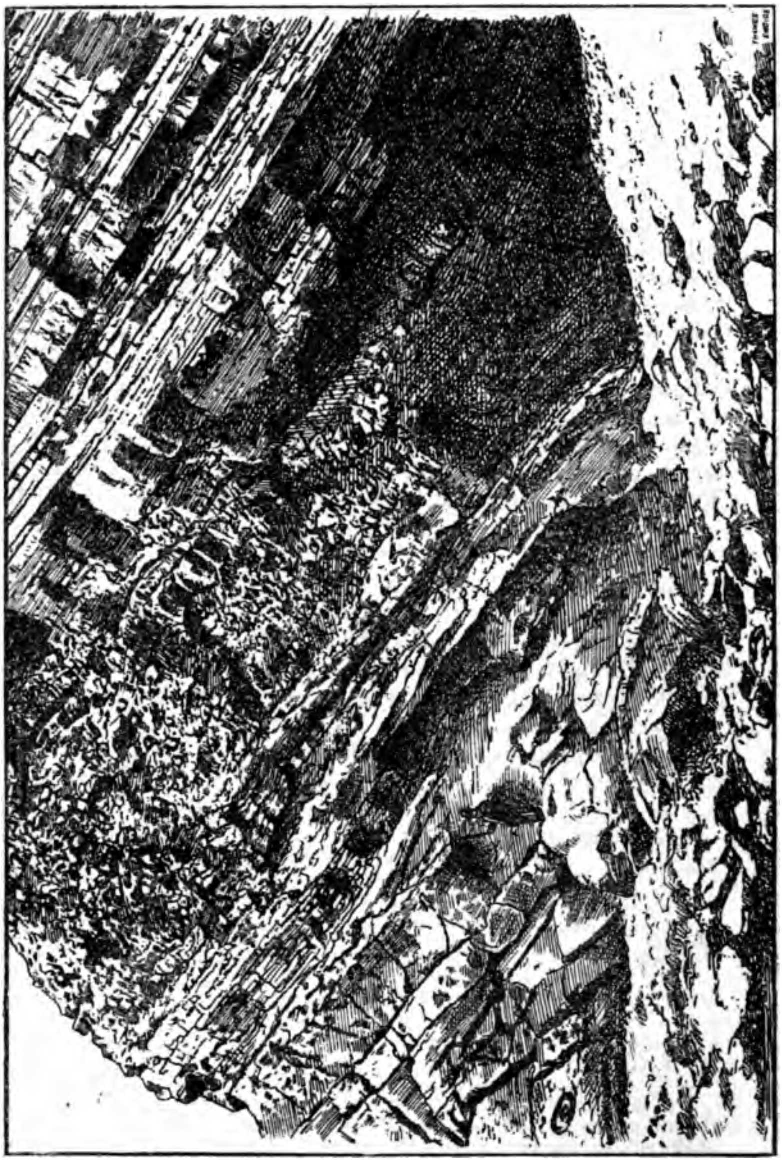


FIG. 125.

Junction of Portland Stone (with Ammonites giganteus) and Lower Purbeck caps and "broken beds." Pondfield near Worbarrow (Drawn by H. W. G. Williams from a photograph.)

round which they could have been built, but here and there grains of calcite showing that the limestone has not always been completely replaced.

The limestone itself shows no trace of organisms, and is made up entirely of crystalline grains of calcite without crystal edges, even where bordering the cavities, although here the grains are larger in size.

These observations are quite consistent with the idea that the limestone has been a cavernous tufa subsequently silicified by percolation of water bearing silica in solution.

On the west side of the Tout the whole group, with the exception of some of the upper beds, is exposed. It will be noticed that much of the Lower Purbeck marl of the Durlston Bay section has been replaced here by limestone, while on the other hand the Swanage building-stones have lost importance. Gypsum occurs at about the same horizon as at Durlston. The Cinder Bed and a limestone seven feet below it, with black flints, stand out conspicuously, the former cropping out on the hill-top a few yards south of the flagstaff. The Unio-beds form a steep face of rock 12 yards south of the Lifeboat House, and are followed northwards by the following strata:—

Worbarrow Bay.

		Ft.	In.
Wealden:—	White sand and red clay, the base running under the north end of the Coastguard cottages		
Upper Purbeck.	Grey clays with ferruginous bands and nodules containing *Paludina* ... ... Gap; partly blue red and purple shales ... } about	50	0
	Paludina-limestone, red at the top, under the south wall of the Lifeboat House	2	0
	Gap, chiefly blue clay	8	0
	Paludina-limestone	1	10
	Gap	1	0
	Limestone	0	1½
	Shelly shale	0	2
	Green marly limestone with *Unio*	0	2
	Limestone and marl in thin beds	0	11
	Shale	0	3
	Hard shelly limestone, *Paludina* abundant on top	0	10
	Shales with calcareous band and "beef"... ...	4	3
	Green limestone with *Unio*, 12 yards south of the Boathouse		

The separation of Purbeck from Wealden, always arbitrary, is here additionally difficult from the obscurity of that part of the section. According to Bristow's measurements (Vertical Sections, Sheet 22) the thickness of the Upper Purbeck at Worbarrow is 49 feet 3 inches, of the Middle Purbeck 89 feet 6 inches, and of the Lower Purbeck 152 feet, giving a total of 290 feet 9 inches.

Mupe Bay.

A small cove to the west of the Mupe Rocks affords the most complete section from the Wealden down to the Portland Stone on the whole coast. So far from helping in the separation of the Purbeck and Wealden groups, the evidence only confirms the completeness of the passage of the one into the other. The following section was measured in company with Mr. H. B. Woodward:—

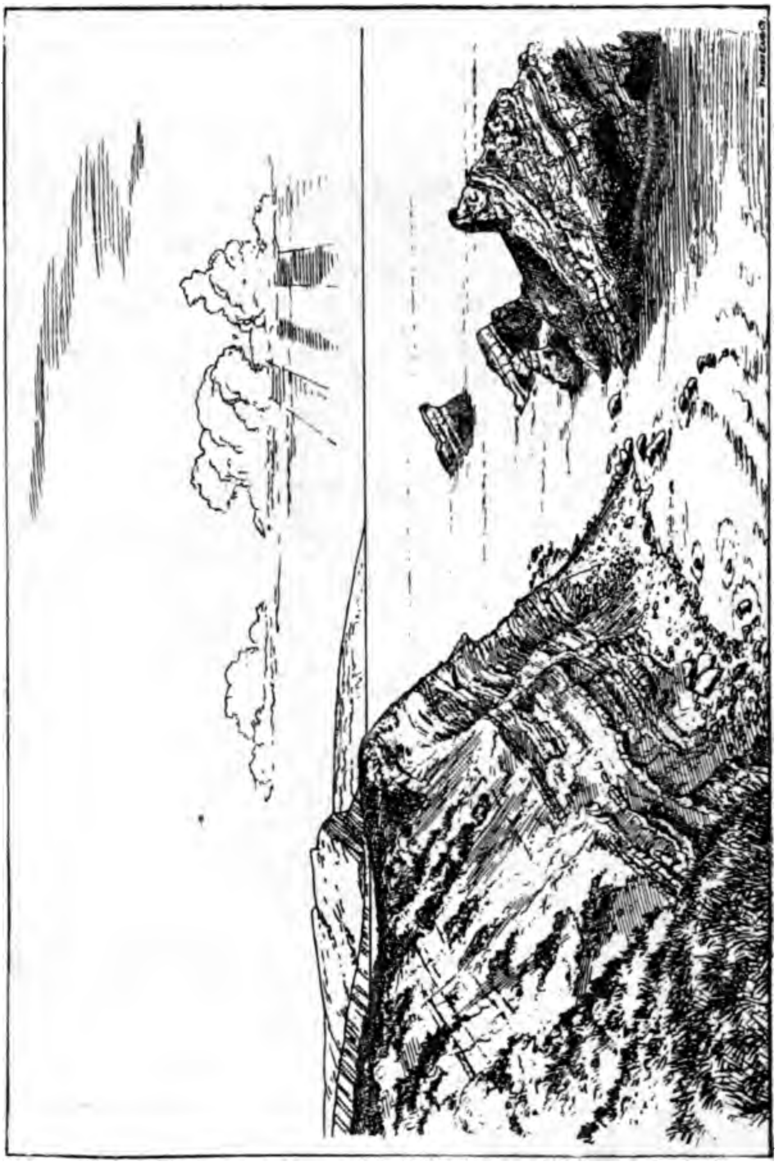


FIG. 126.

Wealden, Purbeck, and Portland Strata, Bacon Hole, Mupe Bay.
(Drawn by H. W. G. Williams from a photograph.)

Bacon Hole, West of Mupe Bay.

		Ft.	In.
Wealden :—	White sand-rock	3	0
	Laminated sand and clay	3	0
	Clay with laminæ of sand	3	0
	Band of clay-ironstone	0	2
	Clay with laminæ of sand	1	6

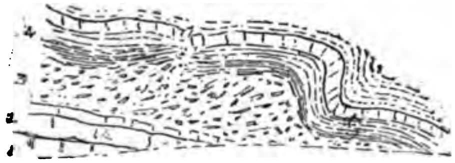
(The division between Wealden and Purbeck may be arbitrarily taken here).

Upper Purbeck.	Ironstone with *Cypridea punctata* (E. Forbes) and *Cypridea tuberculata* (Sowerby), var. *adjuncta* (Jones)*	0	1
	Marly clay	2	0
	Greenish clay with much lignite	2	6
	Greenish blue clay	4	6
	Red calcareous clay with *Paludina*	0	8
	Greyish blue clay	3	0
	Reddish clay with bones of turtle	1	0
	Grey clay	1	0
	Reddish and mottled clay with *Paludina* abundant	2	0
	Greenish shelly limestone	0	4
	Shell-marl with lignite	0	6
	Mottled clay	2	0
	Shell-marl	0	3
	Mottled clay with *Paludina*...	2	6
	Paludina-limestone or "Marble," containing also *Unio*	0	9

The "Broken-shell" Limestone and Cinder Bed with the limestone between them once formed a natural breakwater on the south side of Mupe Bay, but were quarried down to the sea-level some years ago. A second and still more ruinous natural breakwater marks the outcrop of the Portland Stone. It has, however, been broken up by the sea into a row of about fifteen separate stacks, four of which still retain a small cap and pinnacle of Lower Purbeck tufa and "broken bands." In Bacon Hole, as remarked by Mr. Woodward, "a cave has been formed at the junction of the Portland and Purbeck Beds, by removal of slabs of the Hard Cap. The Lower Purbeck beds here include brecciated and banded layers, and the Hard Cap is separated from the Soft Cap by a Dirt Bed containing pebbles of limestone. The Soft Cap is much broken in places, and, indeed, merges upwards into the 'Broken Bands.' These again are overlaid by the Cypris Freestone, also much shattered and broken in places. The upper portions of the Hard Cockle Beds stand out in prominent bands, overlaid by the Soft Cockle Beds, and higher up the cherty limestone again forms a hard band, and, together with overlying Cinder Beds, runs out in ledges on the shore." (Jurassic Memoir, vol. v., p. 255.)

FIG. 127.

Section at Bacon Hole, Mupe Bay (H. B. Woodward)



4. Shales and bands of limestone.
3. Broken Beds.
2. Caps.
1. Portland Stone.

About 20 feet shown.

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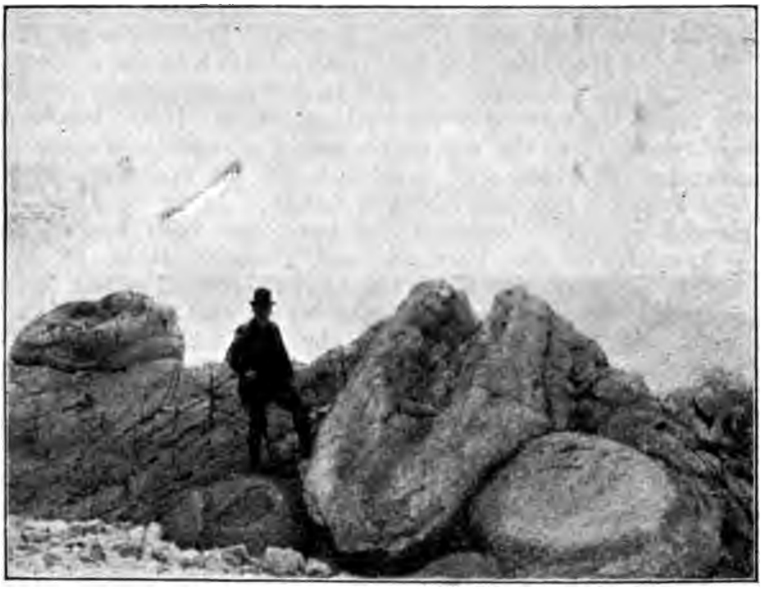
* These determinations were kindly made by Prof. T. Rupert Jones, F.R.S.

The thickness of the Upper Purbeck at Mupe Bay, according to Bristow (Vertical Sections, Sheet 22), is 50 feet 5 inches; of the Middle Purbeck, 57 feet 4 inches; and of the Lower Purbeck, 142 feet 11 inches, giving a total of 250 feet 8 inches.

About midway between Bacon Hole and Lulworth Cove there occurs the most remarkable exhibition on the whole coast of the Dirt Bed, with numerous trunks and stools of trees, and of the "broken bands" above it. The lower and vertical part of the cliff consists of Portland Stone, and a broad ledge above, not difficult of access, gives the view alluded to. The ledge itself consists of the Hard and Soft Caps, the Dirt Bed between them being frequently exposed as a black gravel with pebbles of limestone ranging from 6 to 18 inches in thickness. This rests on an undulating and ripple-marked surface of the tufa below, or Hard Cap. Another impersistent parting or possibly dirt-bed occurs 5 feet lower in the tufa, and by looking over the edge of the ledge we can see that that rock rests directly upon the Portland Stone, with a sharp and slightly undulating junction, but without evidence of actual discordance. This junction lies about 15 feet below the principal Dirt Bed.

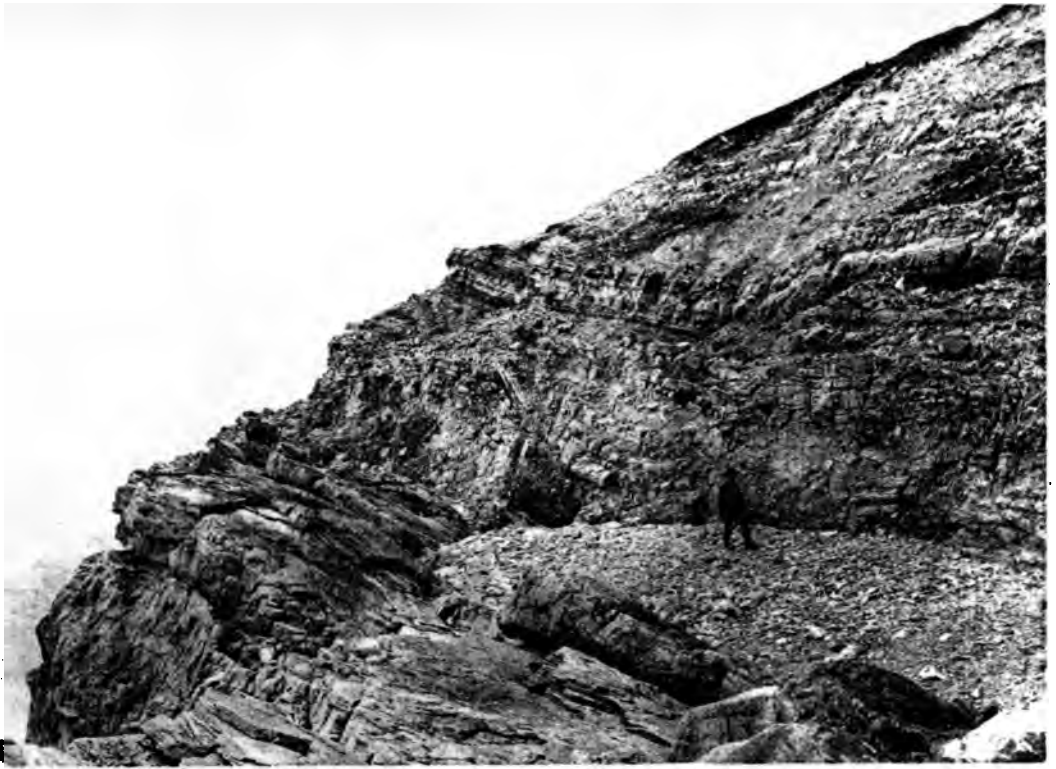
FIG. 128.

Tree-stumps and fallen trunk in Lower Purbeck tufa, near Lulworth.
(From a photograph.)



Above the Dirt Bed lies another very irregular mass of tufaceous limestone, the Soft Cap, from 2 to 4 feet thick, which encloses the trees referred to. As a general rule the tufa completely envelopes the tree, or rather stump, rising into a rounded protuberance in order to do so, but in many the boss or "burr" thus

Plate III.



"BROKEN BEDS" NEAR LULWORTH.

9c20 8 97

formed has a hollow in the top, narrowing downwards conically till it reaches the apex of the tree-stump.

Where a stump is enclosed the boss is round, or nearly so, but when a prostrate trunk constitutes the nucleus the coatings of tufa assume an oval form (Fig. 128). Black chert not infrequently wraps round the upper part of the boss, and the tree-trunk itself has often been replaced by silica. All the characters described above are admirably shown in the large numbers of "burrs" which stud this ledge of the cliff, and one "burr" in particular, slightly shifted from its original position and broken in half, displays its internal structure and still contains remnants of a silicified tree-trunk. This specimen is illustrated in Plate II., in which also is seen the "soft cap" with a hollow beneath it caused by the weathering out of the gravelly dirt-bed.

Directly upon the irregular surface of this tufa rests a tufaceous limestone, undulating and varying from 1 to 2 feet in thickness, and this is immediately succeeded by the "broken bands" to which allusion has already been made (p. 80). Examination of the cliff at different points at once shows that the brecciation does not always extend upwards to the same horizon in the series. Thus, strata which are undisturbed at Worbarrow and Lulworth are "broken" in this intermediate section, and the Cypris Freestone of Bristow's section of Lulworth, together with the lower 3½ feet of the Hard Cockle Beds, are all involved in ruin. The bed described by him as "Dark grey, thinly laminated shale and marl, with thin layers of sandy limestone, more finely laminated and more marly and weathering pale in the lower foot, 2 feet 2 inches," is that which was observed by Mr. Fisher to fill inequalities in the surface of the "broken beds." About 25 feet of strata have therefore contributed to the breccia in this cliff.

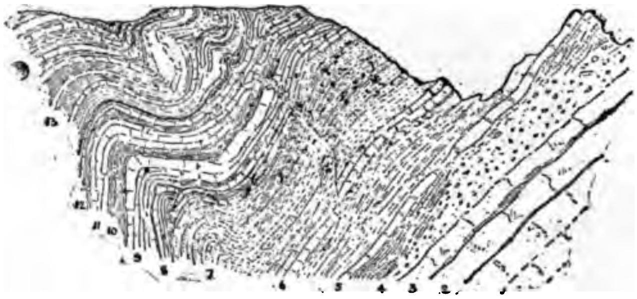
To illustrate the points referred to in the above description, Plate III. has been prepared from a photogravure, for which I am indebted to Mr. H. Wilmer. The junction of the Purbeck and Portland strata is conspicuous on the left, near the top of the vertical cliff. The "caps" with several "burrs" form the inclined platform, immediately upon which lie the "broken beds," showing the stages by which complete brecciation is reached. Above them are seen undisturbed limestones.

Lulworth.

The east side of Lulworth Cove shows a rather less marked development of the same features. The brecciation is comparatively trifling and the "burrs" are not so numerous or accessible. Some contortions, however, in the Upper Purbeck group, obviously connected with the Isle of Purbeck disturbance, call for notice. The Cinder Bed and strata below it dip at about 30° northwards, but the former, just at the sea-level, is bent sharply up for a few feet before finally disappearing. On a close examination of the comparatively soft strata lying above the cinder we find this little Λ-shaped fold growing in importance, until in the *Unio*-beds it measures between 20 and 30 yards from foot to apex. The Λ being placed somewhat on its side the strata of its northern limb are inverted, and this inversion continues through the Marble beds of the Upper Purbeck and far up into the Wealden. Among the inverted strata a band of *Paludina*-limestone can be detected, but most of the clays seen at this horizon at Worbarrow and Mupe Bays are squeezed out. The same type of disturbance can be traced along the Upper Purbeck outcrop west of Lulworth, and is particularly well seen in Stair Hole.

Fig. 129.

Diagram-section of part of Stair Hole, Lulworth (H. B. Woodward).



8. Marly Freshwater Beds.
7. Soft Cockle Beds.
6. Hard Cockle Beds.
5. Cypris Freestones.
4. Broken Beds.
3. Soft Cap.
2. Hard Cap.
1. Portland Stone.

} Lower Purbeck.

13. Corbula and Beef Beds.
12. Scallop Beds.
11. Intermarine Beds.
10. Cinder Bed.
9. Cherty Freshwater Beds

} Middle Purbeck.

At Dungy Head, however, a part of the fold is exposed in which the squeezing was still more intense, with the result that not only the Upper Purbeck but most of the lower division is nipped out, in the manner shown in Plate IX. The Beef and Cinder Beds serve to show the horizon of what remains of the Purbeck group.

The same sort of squeezing accounts for the absence of the lower part of the Wealden, all the Upper, and much of the Middle Purbeck at Durdle Door. The plane of squeeze coincides with the bedding, and but for the absence of certain members in the well-known sequence of Purbeck rocks would have been difficult to detect. Similar squeezes probably occur in the Wealden and certainly in the Upper Cretaceous Rocks (p. 179).

The thickness of the Upper Purbeck of Lulworth according to Bristow and Whitaker (Vertical Sections, Sheet 22) is 27 ft. 6 in., of the Middle Purbeck 55 ft. 4 in., of the Lower Purbeck 93 ft. 5 in., giving a total of 176 ft. 3 in. An exact measurement, however, is impossible in consequence of the distortion of all the softer members of the group; the true thickness is without doubt considerably greater than that shown in the cliff.

The series of coast-exposures of the Purbeck Rocks ends with those incomplete and distorted sections,[*] but the complete sequence is preserved still further west at Ridgeway. We now return to the eastern part of the district for the purpose of describing in order the inland sections, of which the Ridgeway forms part.

INLAND SECTIONS.

Swanage to Worbarrow.

Within this tract are situated nearly all the quarries from which the well-known Purbeck Stone is raised, most of them, in fact, lying within a mile to the south-west of Swanage, while much of the town itself is built upon the spoil from old workings. The bands in requisition occur in the Middle Purbeck and just above the Cinder Bed. There are nearly a hundred quarries, all of which are worked underground by means of inclined planes, or drift-ways cut across the bedding. The industry is ancient, and the stone was largely "used in rebuilding London after the Fire, particularly St. Paul's Cathedral; and for paving the streets and courts." It was employed also in Westminster Bridge in 1750, and of late years in Ramsgate Pier.[†] Peculiar privileges were claimed by the quarrymen, and none were admitted to the company save the direct descendants of quarrymen. The stone is now shipped at Swanage, but was formerly carried to Owre on the Poole estuary, the right of way thither being preserved by articles dated 1697-8, in which "provision is made for a football to be carried to Owre, and a present to be made of one pound of pepper as an acknowledgement. . . . ."[‡]

The "Marble Beds" crop out under the main street of Swanage, and have been quarried almost continuously for five miles westwards. They seem to have been worked, like the building-stone, by inclined planes, but the quarries are now full of water and mud. According to Hutchins columns of Purbeck marble were placed in Salisbury Cathedral in 1258, and it was more recently quarried at Woodyhyde for the restoration of the Temple Church in London. "The quarries resorted to in the thirteenth century seem to have been mostly situated at Quarr and Downshay" (Hutchins, p. 466). Of late years the marble has been raised by means of shafts in a few places only, when occasion arose.

The pit referred to by Mr. Woodward as being open in 1884, and situated just south-east of the farm buildings at Easton, lies

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[*] The small exposure of Holworth near White Nothe is taken with the Osmington Sections (p. 107).

[†] *Hutchins' History and Antiquities of the County of Dorset.* 3rd. Ed. by W. Shipp and J. W. Hodson, p. 464.

[‡] *Ib.* p. 683.

150 yards north of the farm now known as Coombe, half a mile east of Langton. He gives the following section:—

Upper Purbeck Beds near Langton.

	Ft.	In.
Two bands of marble—the upper bed 2 to 3 inches thick: the lower 4 to 5 inches. The beds are broken up, and only remnants occur in the soil.		
Flaggy marble, much weathered: *Paludina* on joints ...	0	8
Shales with "race," and thin flaggy limestone	4	0
Paludina-marble, much broken by joints, and occurring in interrupted masses	0	3
Clays and calcareous shales with "race"	5	6
Brown limestone, blue-hearted	0	4
Paludina-marble	0	6
Shaly parting	0	1
Paludina-marble, irregular bed	0	3
Calcareous shales with "race" and thin limestone-bands	1	6
Paludina-marble	0	7
Paludina-marble	1	4
Paludina-marble (another bed just exposed)		

The marble at this quarry is variable, and green, bluish-grey, and occasionally red in colour—where iron-stained; it generally weathers brown outside. (Jurassic Memoir, vol. v., p. 254.)

In a shaft 600 yards west of Downshay the main bed proved to be two feet thick, while an old quarry 800 yards further on showed three feet of marble. Between Scoles Farm and Blashenwell a sharp little syncline, probably akin to the folds seen in the Upper Purbeck near Lulworth, introduces a narrow outlier of the Marble Beds. South-west of Orchard the rock is being quarried for use in the Cement Works at Newfoundout, and it is worthy of note that the Memorial Church at Kingston, Isle of Purbeck, was built entirely from stone and marble raised on the estate. At Orchard the long line of marble quarries ceases, but blocks of marble up to a foot in thickness occur along the outcrop south of Steeple, and the bed exists in a more or less attenuated form as far as Mupe Bay.

Throughout the whole of this area the outcrop of the Cinder Bed is easily traced, and forms a guide to the horizon of the innumerable quarries. A small outlier of that rock survives in a fragmentary condition on the hill south-east of Worth.

Chaldon, Poxwell, Osmington, and Bincombe.

A small exposure of Upper and Middle Purbeck strata marks the axis of the Chaldon anticline, and some old limestone-quarries in them are said to have been opened for stone for Burton Church. On the south side the Purbeck strata dip gently beneath the Wealden, but on the north side are unconformably overlain by, or possibly faulted against Upper Cretaceous Rocks.

The long narrow outcrop round the Poxwell anticline gives the whole sequence on its south side. The Cinder Bed, and occasionally the Beef Beds, can be identified, but the position of the Upper Purbeck is only inferred. The numerous quarries are all in the Lower Purbeck limestones, and one of them yielded the following section:—

One hundred yards east of Poxwell Lodge.

		Ft.	In.
Lower Purbeck.	Laminated limestone and shale	6	0
	Hard tufa with silicified trees in the lower part..	5	0
	Dirt-bed	0	½
	Tufa	0	6 to 8
	Dirt-bed	0	½
Portland Stone, with many fossils, seen to		6	0

North of the Home (or Grove) Farm the Beef and Cinder Beds are well exposed, and the base of the Purbeck is again visible:—

Two hundred yards north-west of the Home Farm.

		Ft.	In.
Lower Purbeck:—Tufa		3	0
Portland Stone	Chert with fossils	0	2
	Limestone with fossils, seen to ...	3	0

Osmington Church and much of the village stands on the Beef Beds at the west end of the Upton syncline. Curving round to the south and then to the east the Purbeck group passes under the horizontal Upper Greensand of Sandy Barrow, but emerges again for a few yards in the valley near Osmington Mills, where, however, a few overgrown pits and fragments of Cinder and Beef in the soil furnish the only clue to their position. From this point to Holworth they are concealed again beneath the Greensand, but east of the north and south fault at that house the Lower Purbeck occur in their proper position on the top of the Portland Stone. The section here exposed was measured by Mr. Woodward.*

Holworth House, White Nothe.

		Ft.	In.
Lower Purbeck Beds.	Creamy limestones and shales	—	
	Hard marls, sandy and granular oolitic beds with one or two chert-bands: *Cypris purbeckensis*..	—	
	Fissile limestones (Purbeck "slates") ...	5 to 6	0
	Hard creamy marl	1	2
	Thin irregular dirt-layer	0	1
	Hard irregular bituminous limestone	2	6
	Dirt-bed with irregular calcareous seams ...	0	1
	Irregular decomposed sandy limestone	1	0
	Laminated clay and dirt with fish-remains ...	0	2
	Pale compact bituminous and cherty limestone with casts of *Cyrena*; sandy at top	1	3
Portland Stone.—Irregular beds of "Roach," chalky limestone and oolite (see p. 68).			

The position of the Purbeck base on Chalbury and the adjacent hill west of Bincombe is marked by frequent appearances of the massive tufa ("cap") associated with the dirt-beds, though the actual junction with the Portlandian is rarely visible. The best exposure is furnished in the quarry on the south-west side of the camp, of which the section is given on p. 69.

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* "Jurassic Rocks of Britain," vol. v., p. 259.

The limestones above the tufas were formerly worked under ground for use in Dorchester. They lie nearly horizontally, but suddenly plunge down northwards at 70° near the Ridgeway Fault at Greenhill Barton. The same steep inclination is observable west of the Bincombe overthrust mass of Lower Oolites, but the strike slightly diverging from the line of fault soon leaves room for some Wealden to come in between the Purbeck and the faulted Chalk.

Ridgeway, Upway, and Portisham.

The cutting for the approach to the Bincombe Tunnel furnished data for a section by Mr. Fisher,* which was included by Bristow in the series of Purbeck sections forming Sheet 22 of the Vertical Sections of the Geological Survey. The railway-cuttings had been described by Mr. C. H. Weston and Captain L. L. B. Ibbetson†, "who gave detailed measurements of the strata, but included with the Wealden division some beds that were subsequently grouped with the Purbeck Beds by Messrs. Bristow and Fisher, while they included with the Portland Beds strata shown by Forbes to be Purbeck."‡ (Jurassic Memoir, p. 259.) The true base of the Purbeck can be seen in the quarries 200 yards west of the railway, in one of which the following details were observed:—

Upway Quarry.

		Ft.	In.
Lower Purbeck.	Laminated limestone	5	0
	Massive limestone, "broken" in places at the bottom	7	0
	Yellow clayey parting	0	1
	Limestone, very irregular, the lower 2 feet a tufa	6	0
	Dirt-bed Laminated brown earth	0	2
	Dark earthy gravel (the fragments small)	0	4
	White limestone with nests of brown chert weathering into a white impalpable powder	4	0
	Laminated limestone with chert-nodules at the base	5	0
	Shale and laminated limestone with chert ...	1	6
	Fine hard limestone full of small shells (*Cyclas?*)	1	3

adhering to

		Ft.	In.
Portland Stone	Oolitic limestone with Portlandian fossils ...	2	6
	Chert, dense black	0	1
	Limestone	2	6
	Chert-nodules, dense black	—	
	Soft white limestone like chalk; black chert in small twig-shaped nodules and other shapes ...	12	0
	Chert-nodules, dense black	—	
	Soft white limestone as above	1	0
	Chert-band, dense black	0	1
	Fine creamy limestone	5	0
	Beds not seen, about	18	0
	Limestone with numerous large nodules of black chert, seen to	20	0

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* *Trans. Cambridge Phil. Soc.*, vol. ix., p. 4, 1855.

† *Quart. Journ. Geol. Soc.*, vol. viii., p. 116. See also Weston, *ib.*, vol. iv., pp. 252-254.

‡ Geikie, *Memoir of Edward Forbes*, p. 463.

The lowest band of the Purbeck and the top bed of the Portland Stone are quarried out in one block, but the two separate cleanly and easily when hammered, so that it is not easy to get a hand-specimen showing both. The Dirt-bed, though thin at Ridgeway, contains large tree-trunks. "The surface seems to have been covered with fresh water before it was a forest, and just beneath the ancient mould is a band covered with the scales of fish (*Histionotus breviceps*). The thickness is only four inches. . . Then we have another four-inch band, equally abounding in the remains of a very large species of Archæoniscus. . . . This bed at a spot six miles to the east (Upton) is full of casts of a small Paludina."*

At the horizon of the "broken bands" there sometimes occur at Ridgeway, according to Mr. Fisher, laminated shales containing impressions of the wings of insects and scales of fish, but no shells. Brecciation, however, is not absent at the horizon, as we see in the above section, but its comparative insignificance here, close to the Ridgeway disturbance, is difficult to explain on the supposition that it is due to post-Cretaceous earth-movements.

The building-stones worked at Upway belong to the Cypris freestones of the Lower Purbeck, and not to the Middle Purbeck, as at Swanage. Three courses have been worked, and the Top Rock, which is the uppermost member of the Cypris group, contains fish-scales, as well as the *Cypris purbeckensis*, from which the name is taken.

Immediately above the Cypris freestones comes the Lower Insect Bed of Mr. Fisher, a hard, marly rock 1 foot 9 inches thick, with streaky bedding, and containing "a great variety of wings, perhaps more than an average number of them being orthopterous. In this bed, too, is found not unfrequently a small chrysalis, and also a small aquatic insect allied to Notonecta." Three feet above this lies a band of white stone about 3½ feet thick and much used for quoins and other purposes; it is composed of a mass of *Cardia*. This is overlain by the Soft Cockle Beds, characterised by a brackish or estuarine fauna, among which Mr. Fisher mentions *Serpula*, *Corbula*, *Cardium*, *Leda*, *Modiola*, *Ostrea*, and *Cythera*. A hard, marly rock in this group is used for cement-making, and some limestones above are both burnt for lime and employed in interior work.

The Upper Insect Beds of Mr. Fisher, which come next above, lie 16 feet below the Cinder Bed. "In some spots . . . the individual elytra are full as abundant as at Durlstone. A prevailing parallelism of the wing cases, which lie N.N.W. and S.S.E., indicates a particular direction in the current."

The Chert Beds yield specimens of *Physa*, *Paludina*, *Planorbis*, *Valvata*, turtle-bones, fish-teeth, multitudes of *Chara* seeds, &c., some in beautiful preservation. A purplish layer in the upper part contains brackish-water shells, and a shaly stone in the lower part is full of carbonized impressions of a branching aquatic plant.

The Cinder Bed, which crops out at the south end of the short railway-tunnel, consists of two parts—the upper composed of *Ostrea distorta*, and the lower containing also many *Cardia*.

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* Fisher, *Trans. Camb. Phil. Soc.* vol. ix., p. 12 (1855).

The strata above the Cinder, which yield so many turtles and fish at Durlston Bay, are here unimportant, and contain chiefly Cyclades and Cyprides. In the lower part of the Corbula Beds (or Pecten Beds) Mr. Fisher records *Thracia*, *Modiola*, *Perna*, *Pecten*, &c., and notes at their base 2 feet of ripple-marked sandstone, splitting into slabs, the marks indicating a stream from the W.N.W. These beds crop out in the short tunnel in the Ridgeway railway-cutting.

The Upper Purbeck beds are, as noted by Mr. Fisher, on the whole much coarser and more sandy in their texture at Ridgeway than at Durlston, and contain a larger proportion of the spoils of the land, in the shape of lignite and plants, &c. The best specimens of *Unio* have been obtained here, but no insect-remains have been recorded. Small fragments of Paludina-limestone occur in the railway-cutting on the north side of the short tunnel.

The thickness of the Upper Purbeck at Ridgeway, according to Bristow and Fisher (Vertical Sections, Sheet 22), is 49 feet 1 inch: of the Middle Purbeck, 52 feet; and of the Lower Purbeck, 88 feet 4 inches; giving a total of 189 feet 5 inches.

Between Ridgeway and Portisham there is no section requiring special notice. The strata lie in a syncline, which is cut across obliquely by the Ridgeway Fault. The Cinder Bed has been identified at intervals both north and south of the axis, and north of Friar Waddon the soil indicates the presence of mottled clay, which suggests Upper Purbeck, or possibly Wealden. Some of the limestones a little above the Cinder are so impure that at the outcrop, where they have been decalcified, they have left a sufficient residue of white sand to have been worth digging.

Above Little Waddon the tufa at the base of the Lower Purbeck stands out conspicuously. At Portisham the Lower Purbeck and Portland Stone have both been worked, though the latter is now abandoned. The following section was noted in 1890 in the side of the easternmost branch of the tramway shown in the 6-inch map:*—

Quarry, East of Portisham.

			Ft.	In.
Lower Purbeck Beds.	Laminated limestone, undulating so as to fill up hollows of the surface beneath ...	4 to	6	0
	Tufa in great lenticular masses, one of which, measuring 13 × 4 × 3 feet, encloses the trunk of a large tree (Fig. 130) ...	0 to	4	0
	Dirt with lumps of chert and irregular masses of white marl; very irregular, but about		0	6
	Irregular and undulating laminated limestone	0 to	1	6
	Shaly seam		0	2
	Laminated limestone, swelling out at times ...		1	6
Portland Stone.	Fossiliferous limestone		4	0
	Line of large chert-nodules		1	0
	Limestone in beds of 2 to 3 feet each, with chert-nodules; base not seen		10	0

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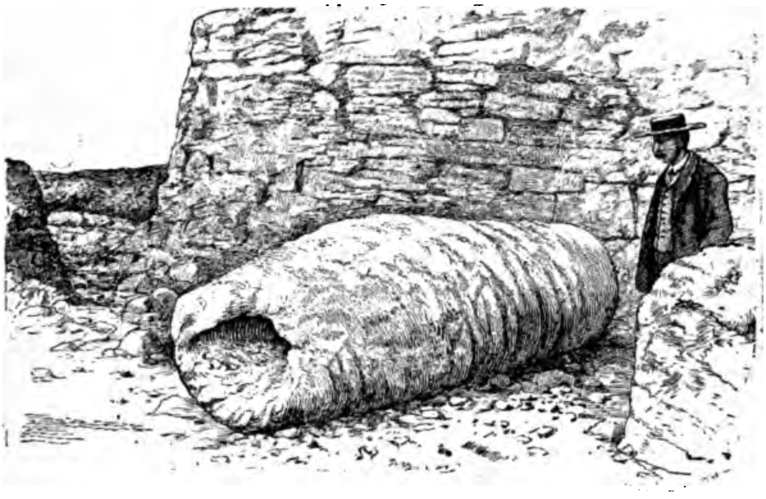
* See also "Jurrasic Rocks of Britain," vol. v., p. 261.

The "tufa in great lenticular masses" is replaced horizontally as well as overlain by laminated limestone. This could be well seen in the side of the cutting just below the drum at the top of the inclined plane. There an erect tree-trunk about eight feet high stood with its base in the Dirt Bed, and in a slight depression in the laminated limestone below the Dirt Bed. The trunk was imbedded in a very irregularly cone-shaped mass of structureless tufa, which was itself surrounded and covered over by laminated limestone. It was obvious that the tree had been broken off eight feet above the ground, but never overturned; the broken stump then formed the nucleus for an aggregation of tufa, at the same time that the laminated material was being laid down in the surrounding water.

FIG. 130

Tufa enclosing a silicified tree-trunk, Portisham



In Fig. 130 is shewn the calcareous envelope of a prostrate trunk found on the lower Dirt Bed at Portisham. The mass was 15 feet long and 3 feet in diameter at its thickest part. The cavity which had originally been occupied by the trunk still retained fragments of silicified wood.

It will be noticed that the Dirt Bed is here only three feet above the Portland Stone, as compared with 11 feet 9 inches at Upway. The difference seems to be due to the absence of the massive tufas of the latter section. A well at "The Buildings" north-east of the quarry was sunk to a depth of 130 feet, and is said to have passed through about 64 feet of Purbeck Beds, and 34 feet of Portland Stone, into the Portland Sand.

CHAPTER VIII.—THE ISLE OF PORTLAND.

General Features.

This island forms the only relic of the Portlandian escarpment of the southern side of the Weymouth anticline, and owes its survival to the hardness of the limestone to which it gives its name. Following the rule usually obtaining in these anticlines the strata dip at a gentle angle southwards,* and the Portland and Purbeck Rocks form a long dip-slope, descending from a maximum height of 495 feet above Ordnance Datum at the north end of the island to about 30 feet at Portland Bill. The Portland Stone forms an almost continuous cliff round the island, inaccessible for the greater part of the distance; the Portland Sand crops out in a steep slope beneath generally overspread by fallen blocks, while the Kimmeridge Clay gives the gentler slopes of the northern foot of the island. Resting on the inclined plateau of Portland Stone the Lower Purbeck strata reach a thickness of nearly 100 feet near Southwell, but thin gradually away to a feather-edge among the stone quarries towards the north. It seems from the description by Webster† and a map by Buckland and De la Beche‡ that the Purbeck rocks must have covered the northern part of the island, though they have long since been completely quarried away.

The waste of the island is proceeding more rapidly than might be supposed from the massive appearance of the rocks. In the northern part it is accomplished spasmodically by land-slips. The sea by clearing the *débris* from the foot of the cliff leaves the Portlandian free to move seawards on the Kimmeridge Clay; great fissures appear in the Portland Stone more or less parallel to the shore, and the rock descends in huge slices, gradually acquiring a steep landward dip, and finally breaking up into large blocks as they descend. The Southwell Landslip south of Rufus Castle presents such features; other landslips have been described by Hutchins as occurring in 1665, 1694-95, 1734 and 1792.§ These slips took place on the north-east side of the island, where their remains still encumber the lower slopes. In 1858 an area of 25 acres of undercliff subsided, causing the sinking of an enormous accumulation of quarry-spoil. Here also the rocks in their descent assumed a steep inland dip, and some garden-plots which had previously sloped towards the sea at an angle of 25°, were turned through an angle of 90° so as to slope

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* The exact dip has been determined by fixing the height above the sea of the base of the Purbeck rocks at intervals along the east and west side of the island. At Easton the dip is due south at 1 in 27, at Weston S.9° E. at 1 in 43, and in the southern part of the island S.31° E. at 1 in 44. This gradual swinging round points to the closing in of the anticline at no great distance eastwards.

† *Trans. Geol. Soc.*, Ser. 2, vol. ii., p. 43.

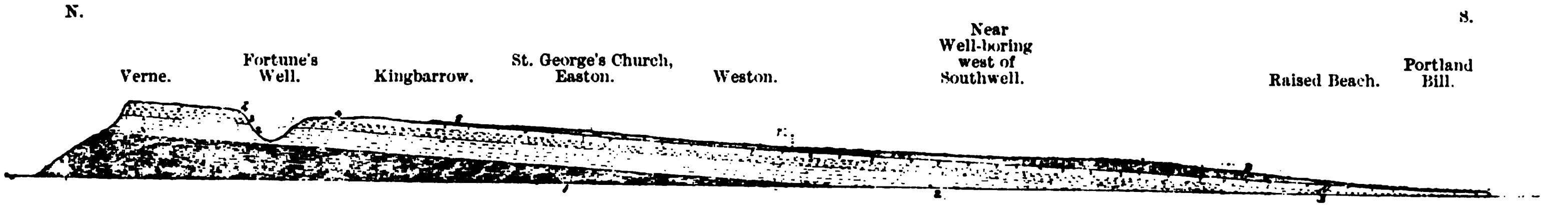
‡ *Ibid.*, ser. 2, vol. iv., Plate 1.

§ *The History and Antiquities of the County of Dorset.* 3rd Ed. by W. Shipp and J. W. Hodson, 1863, p. 826. *See also* W. D. Conybeare and W. Buckland, *Memoir on Landslips*, 1840, p. 9.

FIG. 131.

Section through the Isle of Portland (H. B. Woodward).

Longitudinal Scale 2 inches to a mile. Vertical Scale an inch to 1,200 feet.



5. Purbeck Beds.
4. Freestones. }Upper Portland Beds.
3. Cherty limestones. }Upper Portland Beds.
2. Lower Portland Beds.
1. Kimmeridge Clay.

at an angle of 45° in the opposite direction.[*] As a result of these repeated slips the whole of the outcrop of the Kimmeridge Clay is buried except in the foot of the slope along the north-east shore, while the Portland Sand is only partly uncovered for a short distance under West Cliff, in one or two spots at the north end, in the Prison Tramway to the Breakwater, and for a few yards under Grove Cliff.

Some fissures in the Portland and Purbeck rocks, which were first noticed by Fitton,[†] run in a general N.E.-S.W. direction, and attain a depth of upwards of 30 feet with a width ranging from a few inches to a few feet. In the massive Portland Stone they are usually empty, except for stalactitic deposits, but in the more plastic Purbeck they are choked by the strata having sagged downwards, sometimes without parting. There is no sign at the surface of the existence of these chasms. They may be attributed to the widening of joints, partly by the dissolving away of the limestone walls, but more by differential movements between the massive limestone and the shales above and below them under varying conditions of temperature and moisture. Such phenomena are by no means confined to the Isle of Portland. By Mr. Fisher they were described as the result of a ponderous stone structure having been raised by nature upon a bad foundation. He examined one of them in which bones had been discovered.[‡]

Quarrying and Quarry-Sections.

The quarries for which the island has long been famous seem to have been extensively worked for nearly three centuries. According to Hutchins the stone "first came into repute in the time of James I., who made use of it by the advice of his architects for the banqueting house at Whitehall [built 1619-22]. St. Paul's and many other magnificent edifices were built with it."[§] The total output for the whole island was reported at 24,000 tons in 1839, while 22,995 tons of block with 3,547 tons of roach were conveyed on the Portland railway in 1855. The largest amount thus conveyed is recorded at 81,649 tons in 1865; in 1882 the amount was 45,967. In addition to these amounts between 5,000 and 10,000 tons are computed to have been exported annually in other ways. The above calculation does not include the stone quarried by convicts from the Crown Quarries for various Government Works, or that used in the construction of the breakwater between 1847 and 1862.[||]

The best stone is obtained from the upper or non-cherty subdivision of the Portland Stone. It occurs in two bands, one, known as the "Whit Bed," near the top, and the other, the "Base Bed," near the bottom of the sub-division. Between the two there is a limestone with much chert, known as the "Curf Beds." As nearly all the quarries shew also a varying thickness of

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[*] Damon, *Geology of Weymouth*, &c., 2nd Ed., 1884, p. 158.

[†] *Trans. Geol. Soc.*, ser. 2, vol. iv., p. 218.

[‡] *Geologist*, vol. vi., p. 250.

[§] Hutchins' *History and Antiquities of the County of Dorset*, 3rd Ed.

[||] These statistics are taken from Damon's *Geology of Weymouth*, 2nd Ed., pp. 93, 94.

Lower Purbeck strata, it will be convenient to describe the Portland and Purbeck strata of the island together.

The following sections of quarries have been selected with a view to illustrating the changes undergone by the strata in their range through the island:—

*Kingbarrow Quarries.**

			Ft.	In.
Lower Purbeck strata (part of).		Platy or laminated limestone, broken and weathered ("shifting rubble")	6	0
		Yellow Clay	1	0
	13.	Massive laminated limestone ("hard slate")	4	0
	12.	Hard streaked stone ("bacon-tier")	2	0
		Greenish clay, about	0	2
	11.	Fine-grained argillaceous limestone, drying very white; used for holystone ("Aish-tier")	2	0
	10.	Tufaceous limestone, used for building in the Island, chiefly in chimneys ("burr")	1	4
	9.	Dark carbonaceous clay with fragments of limestone and wood ("top dirt-bed")	0 to 1	0
	8.	Tufaceous limestone ("gristle"); in the lower part traversed by holes ("chaff-holes") 2 to 8 inches in diameter and 5 to 6 feet long, sometimes branching and filled with fossil-wood. The holes are generally nearly horizontal or slightly inclined ("top-cap") about 8 ft.	or 9	0
		Carbonaceous clay and gravel ("lower dirt bed") 3 inches	to 0	6
	7.	Hard brown tufaceous limestone about 1 to 2 feet, but very variable ("skull-cap")	1	6
		Carbonaceous parting; sometimes a chert-band with *Ostracoda* ("dirt")	0 to 0	2
Portland Stone (part of)	6.	Oolitic limestone, honey-combed by the empty moulds of *Trigonia*, *Cerithium*, &c. ("roach")	3	0
	5.	Oolitic limestone ("whit-bed")	5	0
		One or two layers of chert ("the rising")		0
	4.	Oolitic limestone ("bottom whit-bed")	3	0
	3.	Limestone with much chert ("flinty beds"), *Ammonites giganteus*	4	0
		Limestone with much chert ("curf")	3	6
	2.	Oolitic limestone with numerous casts of *Trigonia*, &c. ("base-bed roach")	1	0
	1.	Oolitic limestone ("base-bed")	6	0
		Section continued in an inclined plane leading to the quarries of Messrs. Steward & Co.		
		Parting	0	3
		Hard limestone... 1 ft. 6 in.	to 2	0
		Limestone with chert ("chert-beds"). About 8 feet below the "base-bed roach" lies a limestone with interlacing threads of chert (the "flint-bed") which runs through the whole island	55	0
		Evenly-bedded limestone ("flat beds")	2	0
		Massive fossiliferous limestone with some chert	12	0
		Clay, about	6	0
		Limestone, seen to	10	0

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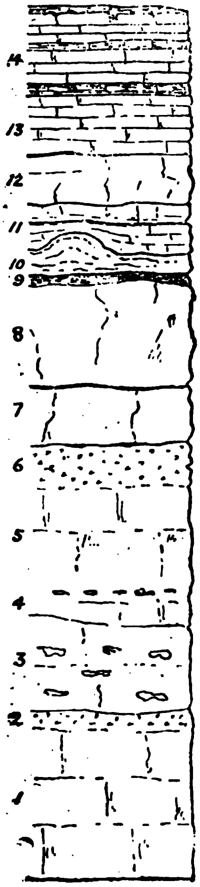
* Measured in company with Mr. A. M. Wallis, by whom the quarrymen's names for the strata were supplied. See also "Jurassic Rocks of Britain," vol. v., pp. 198, 262.

The inclined plane in which the lower part of the section given above was measured shows also*:—

	Ft.	In.
4. Oolitic limestone ("bottom whit-bed")	2	0
3. Limestone with layers of chert about 1 foot apart ("curf")	8	0
2. Limestone, full of casts of *Trigonia*, &c. ("base-bed roach")	1	6
1. Fine oolitic limestone ("base-bed")...	4	0

Fig. 132.
Section at King-barrow, Portland
H. B. Woodward.)



*West Quarries.**

		Ft.	In.
Lower Purbeck strata (part of)	Marl with layers of limestone, top not seen... ...	9	0
	Hard limestone	3	0
	Darkish clay and stone ...	2	0
	White laminated limestone ("slate")	4	0
	Yellowish-green clay	1	0
	13. Hard laminated limestone ("slate") ... ... 3 ft. to	4	0
	12. Hard streaked limestone ("bacon-tier") ... 1 ft. to	2	0
	Clay	0	2
	11. Fine-grained argillaceous limestone ("aish")	2	0
	10. Tufaceous limestone ("burr")	1	0
	9. Carbonaceous layer ("top dirt-bed") from 1 to 12 inches... ... generally	0	8
	8. Tufaceous limestone ("top-cap") with many casts of tree-trunks in white tufa ("chaff-holes") ... 6 ft. to	8	0
	Carbonaceous layer, impersistent	0	3
	7. Hard brown tufaceous limestone (skull-cap) ...2 ft. to	3	0
Portland Stone (top bed of)	6. Limestone full of *Trigonia*, &c. ("whit-bed roach") ...	3	0
	5. Oolitic limestone ("whit-bed"). At the south end of the quarries this becomes nearly all "roach," and is not marketable	12	0

*Flew's Pits, one mile south of the West Quarries.**

		Ft.	In.
Lower Purbeck Strata (part of).	Marls with layers of limestone, top not seen ...	40	0
	Hard limestone ("hard tier")	4	0
	White and dark clay	1	0
	White laminated limestone	6	0
	Clay ... ... about	1	0
	13. Hard laminated limestone ("slate"), in places completely broken up and twisted, though the bed below is undisturbed...	5	0
	12. Streaked limestone ("bacon-tier") 11. Fine-grained limestone ("aish")	4	0

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* Measured in company with Mr. A. M. Wallis, by whom the quarrymen's names for the strata were supplied.

				Ft.	In.
Lower Purbeck Strata (part of).—*continued.*	10.	Tufaceous limestone ("burr")		1	0
	9.	Gravel of limestone-fragments ("top dirt-bed"), resting on a markedly-eroded surface of the bed below	1 in. to	0	4
	8.	Tufaceous limestone ("top cap") with a divisional plane ("rising") in the middle		10	0
		Gravel and carbonaceous earth ("lower dirt-bed")	½ in. to	0	1
	7.	Hard brown tufaceous limestone ("skull-cap")	2 ft. to	3	0
Portland Stone (part of).	6.	Limestone, full of *Trigonia*, &c. ("whit-bed roach")		4	0
	5.	Oolitic limestone, with layers of chert in the lower 2 feet ("whit-bed")		13	0
	2.	Limestone, full of *Trigonia*, &c. ("base-bed roach")		2	0
	1.	Oolitic limestone ("base-bed")		5	0
		Limestone, with a layer of chert in the lower part		6	0
		Chert Dark-grey calcareous chert, about 3 feet thick Black chert		4	0

In this section erosion of the "top cap" beneath the "top dirt-bed" was conspicuous, the gravel constituting the dirt-bed having here and there eaten into the underlying tufa to a depth of 2 feet.

Quarry attached to the Convict Establishment.

				Ft.	In
Lower Purbeck (part of).		Laminated limestone			
		Clay		0	1
		Laminated limestone	1 ft. 6 in. to	2	0
	10.	Hard tufaceous limestone ("burr")	1 ft. to	1	6
	9.	Carbonaceous layer ("top dirt-bed")		0	6
	8.	Tufaceous limestone ("top cap")	8 ft. to	9	0
		Carbonaceous layer ("lower dirt-bed")		0	2
	7.	Hard tufaceous limestone ("skull-cap")	3 in. to	0	9
Portland Stone (part of).	6.	Limestone, full of *Trigonia*, &c. ("roach")		2	6
	5.	Oolitic limestone ("whit-bed")		9	0
		Chert and limestone		3	0
		Limestone, base not seen		0	0

The cliffs near Rufus Castle afforded the following section to Mr. Woodward:—

		Ft.	In.
Lower Purbeck Beds (part of).	Rubble Dirt Bed Cap limestones with thin dirt layers	10	0
Portland Stone.	Oolitic limestone with shelly patches ("roach") at different horizons, and occasional layers and nodules of chert	28	0
	Oolitic limestone with two bands of pale chert near top, and about eight bands of darker chert beneath, in even and irregular layers and nodules, and with an occasional oblique vein of chert	22	0
	Shelly limestome with *Ostrea*	2	0
	Buff sandy limestones with large black scattered flints	10	0

		Ft.	In.
Portland Stone (*continued*).	Limestone with smooth lenticular layers of chert	1	10
	Sandy bed	1	0
	Shelly limestone with thin interrupted but even band of chert; *Ammonites giganteus*, *Trigonia*	2	0
	Very shelly limestone with occasional nodules of chert. (Spring thrown out at base)	6	0
Portland Sand.	Clay (obscured)		
	Hardened calcareous sand, blue and brown, much honey-combed, with crystals of calc-spar; *Ammonites biplex*		

On the west cliff, 350 to 400 yards north of Portland Bill, I observed the following section:—

			Ft.	In.
Lower Purbeck (part of).		Hard laminated limestone ("slate") contemporaneously brecciated or "broken"	8	0
		Hard laminated limestone ("slate")	6	0
	8.	Tufaceous limestone ("top or cap")	6	0
		Carbonaceous parting ("lower dirt-bed")		
	7.	Tufaceous limestones ("skull-cap")	1	0
		Parting		
Portland Stone				

A few yards west of this section the lower dirt-bed was 6 inches thick, and was immediately overlain by 14 feet of "broken" laminated limestone, while 100 yards to the north it was 1 inch thick, and overlain by no less than 30 feet of "broken beds."

Close to the Bill of Portland, but still on its west side, some quarries were worked about 1840 and were reopened in 1889. The measurements here are:—

			Ft.	In.
Lower Purbeck (part of).		Laminated limestone ("slate")	6	0
		Carbonaceous layer ("lower dirt-bed") 1 in. to	0	2
	7.	Tufaceous limestone ("skull-cap")	2	0
Portland Stone (top bed of),	6.	Limestone, full of empty moulds of *Trigonia*, &c. ("roach")	6	0
	5.	Oolitic limestone ("whit-bed")		

From these sections it would appear that the "burr," "upper dirt-bed," and "top-cap" are not represented at the southern end of the island. At Southwell, however, both dirt-beds are shown.

Old quarry in cliff at Southwell

			Ft.	In.
Lower Purbeck (part of).		Laminated limestone	3	0
	10.	Limestone ("burr")	1	6
	9.	Carbonaceous layer ("upper dirt-bed") 6 in. to	1	0
	8.	Tufaceous limestone ("top cap")	5	0
		Laminated limestone 6 in. to	1	0
		Tufaceous limestone, massive	6	0
		Carbonaceous shale ("lower dirt-bed") 1 in. to	0	6
	7.	Tufaceous limestone ("skull-cap") 9 in. to	1	0
Portland Stone				

The greatest thickness of Purbeck strata occurs north and west of Southwell, and there must be not much less than 100 feet of these beds in the cliff about W.N.W. of that village. In 1892 a shaft was sunk for the Portland Urban Sanitary Authority at a point midway between the village and the western cliff, and at a level of 170 feet above Ordnance Datum. The shaft was 230 feet deep, and a boring was made from its bottom for a further 40 feet. At 220 feet depth galleries were driven north, south, east, and west for distances of 35 to 40 feet. The water stood at 172¼ feet from the surface, that is nearly at sea-level, and the yield was about 90,000 gallons a day, but the effect of continued pumping was to draw in salt water. The section proved was as follows :—*

		THICKNESS.		DEPTH.	
		FT.	IN.	FT.	IN.
Lower Purbeck		50	6	50	6
Portland Stone	"Roach"	9	0	59	6
	"Whit-bed"	16	0	75	6
	Rock and strata not described	8	3	83	9
	Impure limestone and "flint"	59	0	142	9
Portland Sands		127	3	270	0
Kimmeridge Clay		---		---	

Subsequently a shaft was sunk in the Chalk in Gould's Bottom near Upway, on the north side of the Ridgeway Fault, at a point 285 feet above Ordnance Datum. The shaft is 102 feet deep with a borehole to a further depth of 60 feet. Water was reached at 75 feet below the surface, and a larger supply was met with at 85 feet. After pumping for some time the yield of the well was found to be above 300,000 gallons in 24 hours.

At the Government Waterworks at Chene, N.E. of Southwell, a shaft has been sunk, and from it upwards of 200 feet of galleries have been driven in the top of the Portland Sand. The water issues from a fissure in the gallery, and the yield has been 50,000 gallons a day. The joints in this cliff run about N.15°E.

Between Easton and Rufus Castle the Portland Stone is overlain by from 14 to 25 feet of Purbeck strata, and in the brow of the cliff north of the Castle by from 10 to 30 feet of those rocks. North of the Prison the Purbeck caps and the upper part of the Portland Stone (whit-bed and base-bed) have been quarried away and the underlying cherty subdivision was being worked in 1890 for a pier at Castleton. Further north again and extending to within 200 yards of the Verne Ditch, there are old quarries levelled and grassed over from which the stone is said to have been raised in 1710. The tramway leading down from this part of the Island to the breakwater gives the following section below the cherty lower beds of the Portland Stone:—

	FT.
Limestone with much chert	
Limestone	6 to 8
Clay	20
Sandy limestone	12

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* The information concerning this well was communicated to Mr. Whitaker by Mr. J. L. Webster.

The same strata were observed by Mr. Woodward at Clay Hope on the west side of the Island as follows:—

Limestones with chert.
Pale limestone with occasional nodules of chert; large Ammonites at the base.

Portland Sand.	Soft marly limestone. Bluish-yellow calcareous sandy beds, much fissured. Irregular bluish-yellow sandy limestone. Thick blue and yellow sandy marls with calcareous concretions and cement-stones.

Kimmeridge Clay.

Kimmeridge Clay.

The poor exposures of the Kimmeridge Clay in the Isle of Portland call for little remark. The uppermost zones are concealed everywhere by talus, and the "coal" which crops out between tide-marks off Castleton, and used to be dug out for fuel, is not easy of access; it is said to have been 10 inches thick. Reference will be made to the more recent formations on Portland in the Chapters dealing with such deposits.

Fossils of the Portland Stone and Sand.

The following notes on the fossils of the strata enumerated in the sections given above, are taken from Prof. Blake's paper on the Portland Rocks of England. The "roach" (No. 6) is characterised by *Cerithium portlandicum* (abundant), *Sowerbya Dukei* (rare), and *Buccinum naticoides* [=*Natica elegans*] (rare), none of which occur in any other bed in Portland. *Trigonia gibbosa, Lucina portlandica, Pecten lamellosus, Ostrea expansa,* and *Natica elegans* survive in this bed from earlier times. The "Whit-bed" (No. 5) contains the true *Ammonites giganteus.* The "curf" (No. 3) contains according to Damon abundant *Ostrea solitaria,* and occasionally *Isastræa oblonga* with its perforating *Lithodomi.* The "base-bed" also contains the *Isastræa.*

Next below is a bed of variable thickness full of *Trigonia gibbosa.* In the Verne Ditch an exceptional thickness of nearly 20 feet of rock is assigned to this band, and it resembles the "roach" except in containing *Perna mytiloides.*

About 10 feet below the base-bed *Serpula gordialis* and *Ostrea multiformis* are abundant. Below this horizon comes the main mass of the cherty series, in which Prof. Blake found *Ammonites boloniensis,* De Loriol, *Trigonia gibbosa, T. incurva* (which does not ascend into the higher beds), and a broad *Perna.* To these beds a thickness of about 26 feet is assigned.

About 40 feet below the base-bed Prof. Blake noted a shell-bed 7 feet 6 inches thick, and abounding in small oysters and *Serpulæ.* From this he obtained *Ammonites pseudogigas, A. triplex* (a very characteristic form), *Pleurotomaria rugata* and *P. Rozeti, Cardium dissimile, Cyprina elongata. Lima rustica, Pecten lamellosus, Trigonia gibbosa, T. incurva,* and *Pleuromya tellina*

This he takes as the base of the Portland Stone. The top bed of the Portland Sand is a stiff blue marl, 12 to 14 feet thick, in which he found no fossils. This presumably is the clay seen in the Tramway as noted on p. 119.

Below it he notes about 26 feet of a liver-coloured mixture of marl and sand, with sandy cement-stones, in which occur *Mytilus autissiodorensis*, *Pecten solidus*, *Cyprina implicata*, *C. elongata*, *Isocardia*, *Ammonites Boisdini (?) and A. biplex.* It rests upon an oyster-bed 7 feet thick and composed of *Exogyra bruntrutana*, and this in turn upon ten feet of yellow sandy beds with *Cyprina elongata* and an *Arca.*

The observations given above were made by Prof. Blake beneath the Verne Fort, but on the western side of the Island he continued his section for 30 feet further in a speckled blue and yellow sandy marl with calcareous concretions (doggers) which passes down into the Kimmeridge Clay. From this he records *Ammonites biplex*, *Natica incisa*, n. sp., *Lima boloniensis*, *Pecten Morini*, *Avicula octavia*, *Trigonia incurva*, *T. muricata*, *T. Pellati*, *Rhynchonella portlandica*, *Discina humphriesiana* and *Pleuromya tellina* in a vertical position.

Two vertebræ of *Cimoliosaurus portlandicus*, which had been known only in the Portlandian, were recorded by Mr. Lydekker in 1890 from the Purbeck beds on Portland Island.*

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* *Quart. Journ. Geol. Soc.*, vol. xlvi., p. 47 (1890). The fossils were wrongly recorded as being from the Cinder Bed, which does not occur on Portland. They were obtained from the Aish Bed of the Lower Purbeck

CHAPTER IX.—LOWER CRETACEOUS.

THE WEALDEN BEDS.

General Account of the Strata.

The sands, grits, and red or mottled clays which compose the bulk of this formation attain a maximum thickness in the Isle of Purbeck of more than 2,000 feet; but like nearly all the other rocks with which we are dealing, they thin away rapidly westwards, though they are still well developed in the furthest known exposure, namely that at Ridgeway. At the eastern end of the Isle of Purbeck we find at the top of the formation some shales, limestones, and sandstone similar to and containing the fossils of the Wealden Shales of the Isle of Wight; the same strata have been detected at Corfe Castle also, but at Worbarrow and westwards they disappear, in consequence of a gradual and conformable overlap by the Lower Greensand. The complete passage of the Wealden downwards into the Purbeck strata has already been noted.

The thinning of the Wealden Beds westwards is accompanied by an increasing coarseness in the sediment, sands replacing clays, and pebbly grits replacing sands in that direction. A coarse grit with pebbles occurs at about the same horizon in all the coast-exposures, and has been noted on the map, but with this exception no horizon can be traced in such irregularly stratified beds for more than a few hundred yards. Lignite occurs abundantly everywhere, and according to Fitton fragments of the trunks of silicified coniferous trees have been found in dark-brown masses in Swanage Bay. Buckland records the finding of bones of Iguanodon on the shore half a mile north of that town,* and Mr. Fisher notes their abundant occurrence in the lowest beds of the Wealden at Ridgeway.†

The character of the greater part of the formation forbids the supposition of its having been laid down in such lagoons as prevailed in Purbeck times, but suggests the action of a river distributing clay, sand, and gravel very irregularly and locally on a subsiding area. For the most part it not only presents no indications of salt water, but gives positive evidence of fresh-water origin in the presence of *Unio* (Fig. 115); the uppermost division however, the Wealden Shales, which persist throughout the South-east of England, the Isle of Wight, and part of the Isle of Purbeck, contain an estuarine fauna, and show a corresponding change in lithological character. They consist principally of dark, finely-bedded muds, with occasional thin limestones and fine sandstones. The disappearance of the estuarine type westwards and the absence of the marine forms in the Weald Clay of Kent combine with the characters referred to above in suggesting that the sea towards which the Wealden River was flowing lay to the south-east.

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* *Trans. Geol. Soc.*, ser. 2, vol. iii., p. 428.

† *Trans. Cambidge Phil. Soc.*, vol. ix., p. 3.

Wealden.

FIG. 133.

Iguanodon bernissartensis, Boul. From the Wealden Beds of Belgium, $\frac{1}{75}$ nat. size. (From the Guide to the Geological Department, British Museum, Part II., fig. 23. 1890.)

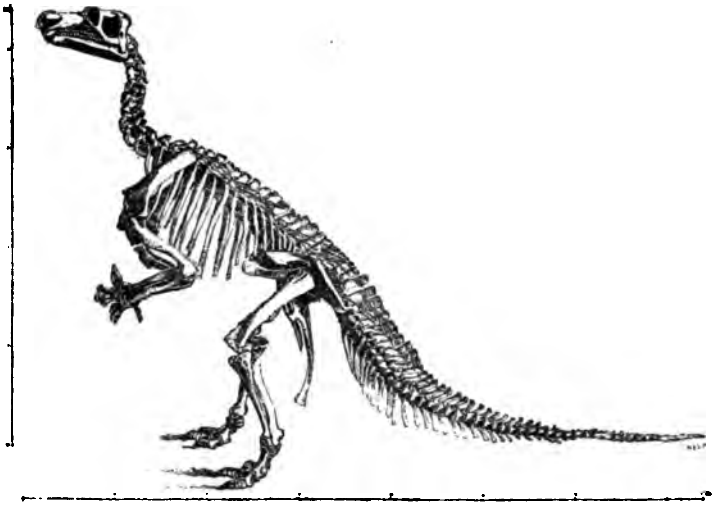


FIG. 134.

Four lower teeth of Iguanodon ; inner Surface
From the Wealden Beds of the Isle of Wight.
(*ib.* FIG. 24.)

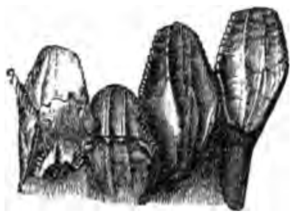


FIG 135.
Paludina fluviorum, Sow.

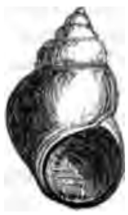
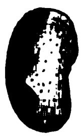


FIG. 136.
Cypridea spinigera, Sow. × 12.

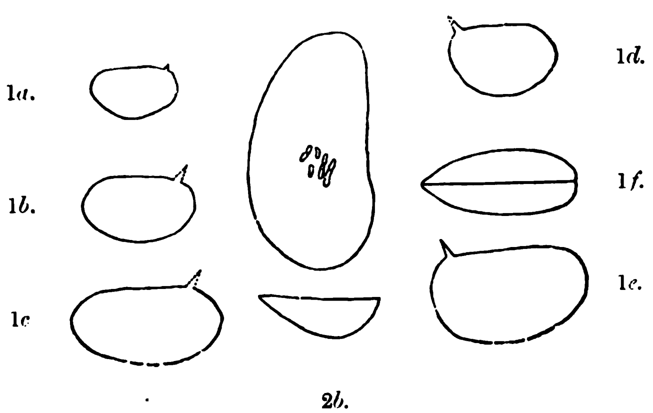


Five great coast-sections of the Wealden fall within the area under description, namely Swanage, Worbarrow, and Mupe Bays, Lulworth Cove, and the Durdle promontory. These we will take in order from east to west, and subsequently note the inliers of Chaldon, Osmington, and Ridgeway.

Wealden.

FIG. 137.

Cypris cornigera, Jones, *Candona Mantelli*, Jones.



Cypris cornigera, Jones.
FIG. 1a. A right valve of a young individual.
" 1b. A right valve of medium growth.
" 1c. A long and low (narrow) variety ; right valve.
" 1d. A short and high (broad) variety ; left valve.
" 1e. The largest specimen ; outline of left valve.
" 1f. The largest specimen ; outline of edge-view of carapace.

Candona Mantelli, Jones.
FIG. 2a. Outline of a right valve. (Anterior end placed upwards.)
" 2b. Outline of the end view of the valve.

Magnified 20 diam. ; drawn by Mr. C. D. Sherborn, F.G.S.

Swanage (Plate XI.) *and Corfe Castle.*

The junction of the Wealden and Purbeck Beds is concealed at Swanage by Alluvium, and the southernmost sections show red clay and yellow or white sand, some 50 or 60 feet up in the former, with a dip of 18° to 20°. Half a mile north of Swanage, where Beach Road turns inland, a cliff commences and continues round the remainder of the bay; here we find in ascending sequence mottled marl and sandstone alternating, then green sand with lignite, sandstone with interbedded shale and lignite, red marl and then three feet of coarse grit with little quartz-pebbles, this last being on the same horizon as a pebbly grit which crops out in the western coves. Still continuing upwards we cross green sandy marl with lignite, a prominent bed of red marl, followed by white sand and ferruginous gritty sandstone, and at a distance of one mile from Swanage arrive at a little ravine extending about 100 yards inland. The dip so far has varied from 18° to 30°, but from this point northwards increases rapidly, until at the top of the Wealden Beds it exceeds 60°. In this distance (about 800 yards along the beach) we pass over sands with a thick band of red clay, white sandy clay and purple clay, and then some white sand and clay with much lignite and some lumps of ironstone containing *Unio* and much selenite, the latter probably derived from the decomposition of iron-pyrites, which is common in all the lignitiferous beds. Above these again some sandstone, purple clays, and red and white clay and sand, in the upper part of which are imbedded broken trunks of trees. Here there is a considerable recess in the cliff caused by foundering, beyond which there occur sandstone and red marl, followed by the beds which are given below in descending order.

Descending section of the Wealden Shales at Punfield Cove, Swanage.

		Ft.	In.
Perna Bed (see p. 136.)			
Wealden Shales.	Blue shale, broken up and redeposited, base not seen	1	0
	Beds not seen	5	6
	Blue shale	2	0
	Band containing *Cyrena*, *Ostrea*, *Paludina*, *Cypris tuberculata*...	0	6
	Blue shale	0	6
	Hard limestone with *Cyrena*, *Ostrea*, *Paludina*	0	6
	Blue shale; *Cypris tuberculata* in the lowest inch	2	0
	Sandy shale	1	0
	Blue shale	4	0
	Hard grit with irregular base from ½ to ...	1	0
	Blue shale, about	1	6
	Soft yellow sandstone	3	0
	Shale and sand...	2	0
	Beds not seen	7	0
	Shale with *Cypris tuberculata*	3	0
Wealden Sands, &c.	Soft white sand, passing down into grey clays and white sands with brown sandstones ...	70	0
	Red marl, as described above.		

From the irregular bedding and the varying inclination of the strata in Swanage Bay it is not easy to obtain direct measurements of the Wealden beds exposed, but an estimate can be made in the following manner:—The total breadth of outcrop is 2,200 yards; in the northern part of the outcrop the dip falls from 62° to 18° in a distance of 700 yards. If we took the mean of 18° and 60° as the average dip in this belt we should obtain about 1,300 feet as the thickness of beds therein contained. The turnover of the strata, however, is usually somewhat rapid, and we shall be nearer the mark in taking 30° as the average inclination, and in assigning a thousand feet of strata to this belt. In the next 500 yards of outcrop the dip averages about 16°, which gives a thickness of 350 feet for this portion. There remains a distance of 1,000 yards in which the dip averages 20°, and in which, therefore, there is room for about a thousand feet of rocks. We thus arrive at 2,350 feet as the total thickness of the Wealden Beds of Swanage Bay.

Following the outcrop inland we are led through an undulating or woody tract, with endless small exposures of sands and red or mottled clays, the former frequently rising into small scarps, but never running for more than a few hundred yards. Windmill Knap, near Godlingston, which presents more than usually bold features of this character, consists of a coarse quartz-grit on the same horizon as the grit mentioned above. At the base of the Wealden Beds a bold scarp runs parallel to and about 100 yards north of the line of old marble-quarries. The feature starts near Wilkswood Farm, passes under Quar Farm, and continues to Woodyhyde, while it reappears at intervals as far as West Orchard Exposures at the first-named two farms show that it is due to a band of hard sandstone from 2 to 3 feet thick resting on soft white sand. Below it we see at Downshay some deep red clay passing down into grey clays, while above it, in the road running north near Haycraft, we get a glimpse of a variegated clay containing a band of greenish limestone with *Paludina*, and again, 60 yards further on, of a grey and mottled clay with a seam of clay-ironstone containing the same fossil. This section prepares us for what becomes clear at Worbarrow and elsewhere, namely, that no line can be drawn which does not either include beds of Purbeck type in the Wealden or beds of Wealden type in the Purbeck, the two formations being absolutely inseparable.

A coarse grit on the same horizon as that mentioned above runs across the northern part of Corfe Common. It is exposed in the railway east of Town's End and again in a pit 200 yards east of the railway, where it is white and more than 20 feet thick. A second marked bed crosses the Common 400 or 500 yards further south. In the cutting where the high road crosses the railway it contains fragments of sandstone and of reptilian bones, as is so often the case in the Wealden Beds of the Isle of Wight.

At Corfe Castle the Wealden Shales are seen for the last time. They, with the Lower Greensand, were crossed in the cutting made for a siding on the west side of the station, and though now grassed over yielded the following measurements to John Rhodes while engaged in collecting the fossils. The beds dip north at 60° :—

Section in the Goods Yard, Corfe Castle Railway Station

		Ft.	In.
Lower Greensand (top not seen).	Brown, white, and red sand and laminated sandy loam	80	0
	Laminated brown and yellow sandy clay ...	30	0
	Blue clay. This and the preceding bed crop out behind a low supporting wall ...	15	0
	Ferruginous shale, with nodules of clay-ironstone, the whole bed full of shell-fragments and lignite	13	6
	Blue and buff fossiliferous clay, pink at the top (Atherfield clay)	20	0
	Band of ironstone with fossils, black pebbles fish-teeth, &c. (? the Perna Bed)	2	0

		Ft.	In.
Wealden Beds.	Hard grey sandstone, irregular ; about ...		1 to 3
	Yellow sand	7	0
	Yellow loamy clay	2	0
	Ironstone and ferruginous clay with *Vicarya strombiformis*	0	10
	Laminated shale (like Cyprid-shale, but no Cyprids seen)	2	0
	Yellow loamy clay and sand...	20	0
	Yellow sand	20	0
	Yellow loam	54	0

The section indicates that the upper division of the Wealden is losing its distinctive character as a shale, and passing westwards into sand and sandy clays. The occurrence of the *Vicarya*, however, links the beds with those of Punfield and the Isle of Wight.

At Steeple the coarse quartz-grit reappears for about a mile. In some pits by the side of the road, 500 yards east of the church, it contains pebbles of quartz of the size of peas, and lignite. It comes in again at Tyneham, and runs thence to the centre of Worbarrow Bay

Worbarrow Bay.

Descending Section of the Wealden Beds.

	Ft.	In.
Lower Greensand. (*See* p. 139).		
Wealden Beds :—		
Irregular ferruginous seam	0	1—2
Grey and ferruginous loamy sand with lignite	6	0
Ochry grit	0	3
White loamy sand	7	0
Conspicuous blood-red or purple iron-band	0	2—4
Red, yellow, and white sandrock	18	0
Grey clay	3	0
White loamy sand	4	0
Stiff blue clay	13	0
Grey sand, bright-buff below...	6	0
Blue clay	10	0
Sand	3	0
Clayey sand	9	0
Black ferruginous sand	3	0
White sand and clayey sand	17	0
Pink sand with deep-red bands	20	0
Grey marls with purple sand in the upper part, and one or two ledges of sand	52	0
Sand with lignite	3	0
Variegated red and grey marl	100	0
Sand	8	0
Purple marls	30	0
Lignite	2	0
Ferruginous grit with lignite...	4	0
Grey or greenish marls	11	0
White sand and clay	9	0
Bright-buff sand with irony veins	13	0
Grey clay	47	0
Purple clay	3	0

Wealden Beds—*continued.*

	Ft.	In.
Grey and purple clay	30	0
Hard grit	2	0
Sand and grey clay	13	0
Tough grey and purple clay	35	0
Very white sand and clay with bands of white sandrock	27	0
Red and green marls	40	0
White loamy sand with lignite and black streaks... ...	21	0
White loamy sand	14	0
Coarse quartz-grit, 6 inches to	4	0
Red marl...	23	0
Fine white sand	15	0
Red and mottled marls	32	0
Alternations of green marl and white sand	66	0
Quartz-grit, inconstant and current-bedded	13	0
Buff and red sands, bright-red above	60	0
Grey lignite with lignite and tree-trunks, one, slightly flattened, measuring two feet across by eight inches in thickness	15	0
Sandstone	8	0
Red and grey clay with bands of sandstone	100	0
Grey marl passing down into red marl	50	0
Sandstone	20	0
Grey clay with much lignite and bands of sand	30	0
Red and green marl	50	0
Grey clay with lignite...	10	0
Red clay...	8	0
Clays with lignite, base not seen	10	0
	1,097	7

Here we reach the mouth of the stream which enters the sea at Worbarrow, and lose the cliff-section; but inland, along or near the banks of the stream, we find red and grey clay, then white sand, and red clay again, the last resting upon a grey clay with *Paludina* in nodules, which passes under the north end of the Coastguard Station, and forms the commencement of the Upper Purbeck. The distance from the stream to this bed is 80 yards, and, with a dip of 36°, allows room for about 140 feet of strata, thus giving the total thickness of the Wealden Beds as 1,237 feet.

Mupe Bay.

In Mupe Bay the Wealden Beds occupy a breadth of 275 yards which, with a dip ranging from 75° in the upper to 50° in the lower beds, indicates a thickness of about 750 feet. A quartz-grit, with pebbles of white quartz up to half an inch in length, occurs 270 feet from the top, and doubtless corresponds to the grit noticed in Worbarrow Bay and elsewhere. The lower beds of the Wealden consist of grey sand with much lignite, followed downwards by red clay and white sandstone, interlaminated with clay. A detailed section of the junction beds of the Wealden and Purbeck, as measured in Bacon Hole, a small bay to the west of Mupe Rocks, is given on p. 100.

Lulworth and Man o' War Coves.

In the cliffs at Lulworth the quartz-grit forms a marked feature. The strata above it occur in the following sequence:—

Upper part of the Wealden Beds on the East Side of Lulworth Cove.

	FT.	IN.
Gault. (*See* p. 152.)		
Strong line of erosion.		
Grey sandy clay...	1	0
Concretions of iron-oxide with numerous fossils, *Cyrena*, *Exogyra*, and a few gasteropods	0	6
Dark-grey shaly clay with yellow stains	5	0
White clay and sand	8	0
Clay with spherical grains of iron-oxide	0	3
White clay and sand	7	0
Reddish clay and a thin band with grains of iron-oxide	1	0
White clay	3	0
Tough greenish clay	6	0
Irony sandstone...	3	0
Red marls with green bands	63	0
Ferruginous sands and red and green clays	132	0
Coarse quartz-grit with much lignite, and with pebbles of white quartz up to half an inch in length	14	0
	243	9

This portion of the group, therefore, has lost 27 feet in thickness between Mupe Bay and Lulworth Cove. This is principally due no doubt to the general attenuation westwards, but, at the same time, the strong line of erosion at the base of the Gault points to some of the beds having been removed. The lower beds of the Wealden are here inverted, so as to have an apparent dip northwards of 70°, a position which is indicated on the map as a northerly dip of 110°. There seem to be about 320 feet of strata between the quartz-grit and the Purbeck, making the total thickness of the Wealden group 573 feet, but the more plastic rocks have been so much squeezed that the measurements are unreliable. A conspicuous band of black carbonaceous sand near the base probably corresponds to the grey sand with much lignite noted in Mupe Bay. On the west side of Lulworth Cove the black band is readily recognised, together with the passage-beds down into the Purbeck rocks, but the upper beds of the Wealden group are cut out by a strike-fault.

In crossing to the next bay west of Lulworth Cove we notice the black band in Stair Hole, and can follow it thence to the beach near Dungy Head, where, however, it loses its conspicuous blackness. At least two faults pass out to sea in this bay, namely, the strike-fault before alluded to, which cuts through the upper beds, and a second parallel fault which throws the Wealden against Middle Purbeck rocks at Dungy Head. Both faults closely follow the bedding-planes, and except in the case of the latter, where we know exactly what portion of the Purbeck formation is missing, we are quite at a loss to determine their effect. The beds occur in the following sequence along the upper part of the cliff from north to south:—

Wealden Beds near Dungy Head.

	Ft.	In.
Gault. (*See p.* 152.)		
Strong line of erosion.		
Tough red and white clay	5	0
White sand, with lignite and bands of quartz-pebbles averaging half an inch in length	21	0
Fault; the exact position among the vertical strata uncertain.		
Red clay	16	0
White sand, with white clayey bands	50	0
White sand, with white clayey bands and darker carbonaceous clays and sands with veins of lignite (the black band of Lulworth)	62	0
Red clay	2	0
Fault.		
Middle Purbeck limestone and shale, with Cinder Bed at base	18	0
Total of Wealden Beds seen, no allowance being made for faults	156	0

The Gault and Wealden are both inverted, the dip of the former being 100° and that of the Wealden 110°. In consequence of this difference the distance from the Gault to the base of the white sand with white clayey bands is 127 feet in the base of the cliff, that is 35 feet more than in the section given along the top of the cliff. This example serves to show how little reliance can be placed on measurements made in soft rocks which have been so squeezed as those of the Lulworth Coves.

In the promontory of Durdle Door the quartz-grit can be recognised close by the base of the Gault. The apparent thickness of the whole group is 200 feet, but the squeezing and thrusting of the strata have been here even more intense and the measurement is altogether untrustworthy. This is the last coast-section of the Wealden Beds.

Chaldon, Osmington and Ridgeway.

Three inliers of this group of rocks fall within the area now under description, namely those of Chaldon, Osmington, and Ridgeway, the last-named being the most westerly exposure of Wealden Beds in the country.

The Chaldon inlier owes its existence to the Ridgeway anticline, which, according to the almost invariable rule in these post-Cretaceous folds, brings up the strata with a gentle dip from the south, and rolls them over with dips of 45° and more towards the north. We have already remarked that the Wealden and all older rocks had been folded and faulted between the Lower and Upper Cretaceous periods, and that this fact is most conspicuously brought out by the mapping at Osmington and Holworth. The unconformity is no less marked at Chaldon, but the relations of the two groups are less easily grasped from the circumstance that the post-Cretaceous Ridgeway anticline has been there superimposed upon strata already affected by the intra-Cretaceous folds. If we restore, in imagination, the Chalk near Lord's Barrow and Five Marys from its present inclination of about 45° to a horizontal position, we shall add 45° of southerly dip to the Wealden and Purbeck Beds. These rocks already dip southwards at an angle of 5° close to the highly inclined Upper Greensand, and must therefore have dipped southwards at 50° before the production of the Ridgeway fold, when the Upper Cretaceous Rocks were still horizontal. On the other hand, along the southern margin of the inlier the Wealden strata dip southwards at about 20°, while the Upper Cretaceous Rocks dip in the same direction at 8° or 10°. Here then if the latter were restored to horizontality the Wealden Beds would have a southerly dip of only about 10° or 12°. We see therefore that the Wealden and Jurassic rocks, before the production of the Ridgeway fold, had been bent into a broad syncline which lay on the north side of the sharp folds of Ringstead Bay, and which was succeeded still further north by a steep anticline now half hidden under the Upper Cretaceous escarpment. The Ridgeway Fold, which came into existence subsequently, cut across the older synclines and anticlines so obliquely that the axis of the later anticline is not far from coinciding with the axis of the earlier syncline in the Chaldon Inlier.

The few exposures of the Wealden Beds near Chaldon show rocks of the character with which we have become familiar in the Lulworth Coves. Much of the sub-soil is red and yellow clay, but here and there beds of sand project in small impersistent features: one such runs east and west for nearly a mile north of East Chaldon, and is exposed as a white sand and grit in a pit in the fork of the Alluvium shown on the map. Two hundred yards north-west of Northground Dairy two pits show six feet of white clay resting on white sand and quartz-grit; the latter reappears at intervals for a quarter of a mile westwards, and not improbably corresponds to the pebbly grit noticed in the coast-sections. At Holworth the Upper Greensand bridges over the valley, apparently owing to a local flattening of the Ridgeway anticline, and so closes in the Chaldon Inlier.

The Wealden Beds, however, re-emerge almost immediately, to form the Osmington Inlier. The quartz-grit which we have mentioned above becomes here more conspicuous; it runs at a distance of about 200 yards from the top of the Purbeck Rocks and can be traced as far as Upton. Below it deep-red clay can be seen at intervals, and above it white, red, and mottled clays and sands of the usual type.

Near Osmington the horizontality of the Upper Cretaceous Rocks shows that such inclination as occurs in the older strata may be attributed solely to the intra-Cretaceous movements. It will be noticed that the Wealden, Purbeck, and Portland outcrops sweep round to the south under and west of the village, and then turn to the east before disappearing under the Upper Greensand of Sandy Barrow. After a brief emergence in the valley which leads to Osmington Mills they pass obliquely for a mile and a half under a down of Chalk and Greensand, and re-issue near Ringstead Dairy. Here matters are complicated by the post-Cretaceous Ringstead movement, which tilts up the Chalk and Greensand at a high angle ; but the northerly dip of the older rocks being steeper than that of the Chalk, we infer that the older rocks must have had a northerly dip before the post-Cretaceous movement, and that we are here on the southern limb of the Chaldon and Osmington intra-Cretaceous syncline. How far the syncline extends eastwards under the Chalk Downs is unknown, but its termination westwards, indicated by the course of the outcrops at Osmington, is well defined. No trace of it has been detected at Preston.

That this syncline was formed after the deposition of the Wealden strata is obvious; there is good reason for believing it to have been later than the Lower Greensand also. The unconformity at the base of the Gault, though only suspected in the Isle of Purbeck, becomes steadily more pronounced westwards, owing to the greater energy of the intra-Cretaceous movements in the western part of the district. On the other hand, the Lower Greensand where last seen in Mupe and Worbarrow Bays, shews a tendency to pass into the Wealden, the signs of erosion between it and the Wealden being less marked than at Punfield and in the Isle of Wight. Moreover, the base of the Gault, as might be expected, is conglomeratic, especially where the unconformity is great. But it possesses this character also in that region where it rests on Lower Greensand, and where the unconformity is not so conspicuous. Lastly, it should be remembered that the disappearance of the Lower Greensand between Mupe Bay and West Lulworth is not improbably due to unconformable overlap. Such evidence as we possess therefore points to the break between Gault and Lower Greensand being greater than that between Lower Greensand and Wealden, and this is true not only of Dorset, but of Wiltshire and elsewhere.

In the third inlier, namely that of Ridgeway, the Wealden beds occur in a narrow strip, bounded on the north side by the Oxford Clay fault described on p. 223. The rocks dip northwards at angles of 40°-54° and are much overgrown, but white sand and grey or blue clay can be distinguished in the upper part, underlain by quartz-grit, perhaps the same bed noticed in the coast-sections. Below this again comes grey and brown clay, and sand resting upon ferruginous clay with lignite and sand, and then the Upper Purbeck strata, which were worked out in detail by Mr. Fisher (p. 109). The total thickness of Wealden strata seen amounted, according to Mr. Fisher, to 350 feet, but this is not necessarily the full thickness of the formation. *Unio* was found by him "in some hard conglomerate-looking bands," and abundant bones of *Iguanodon* "in a stiff grey clay near the base of the series, just above the passage beds which connect these sands and clays with the Upper Purbecks." *

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* *Trans. Cambridge Phil. Soc.*, vol. ix., p. 3 (1855).

CHAPTER X.—LOWER CRETACEOUS ROCKS (*Continued*)

LOWER GREENSAND.

Introduction.

This group is exposed in three coast-sections, namely, at Punfield Cove in Swanage Bay, in Worbarrow Bay, and in Mupe Bay, westward of which it thins out. Of the few inland exposures, the Corfe Castle cutting alone showed any points of interest, and that is now grassed over.

The Punfield section has attracted much attention. Fitton in 1827 identified the Upper Greensand, Gault, Lower Greensand, Weald Clay (Wealden Shales), and Hastings Sands (Wealden Variegated Beds), but gave no details of the Lower Greensand. In 1850 Godwin-Austen noted the abundance of *Cyclades* and *Paludinæ* in the Wealden Shales of Punfield, and expressed a doubt as to the Lower Greensand being represented there at all.* But in 1856 he stated that "Weald Clay may be seen on the W., as at Punfield, in Swanage Bay, to alternate with, and therefore be synchronous with, the marine Neocomian group,"† and he adds, on p. 68 of the same paper, that the marine Neocomian "commences at Punfield on the W. in the form of a thin band of limestone, included in dark Wealden Shales, with much vegetable matter, and containing a curious assemblage of marine, brackish, and freshwater shells."

Professor Judd followed in 1871 by proposing the name of Punfield Beds for a set of strata which he described as consisting of (*a*) shales with thin limestone in the upper part, with the characteristic fossils of the Wealden shales, (*b*) ferruginous sands interlaminated with clays and containing a fauna for the most part marine, and (*c*) a thin band of limestone crowded with fossils, many of which are well-known Lower Greensand forms. These strata were believed by him to rest almost immediately on the variegated Wealden clays and sands, and were correlated with the Wealden Shales, which occur between the Perna Bed (the base of the Lower Greensand) and the Wealden Variegated Beds in the Isle of Wight. He concluded from the fauna that the "Punfield Beds" indicated the "gradual return of marine conditions, which at the termination of the Wealden period ushered in the Upper Neocomian."‡ In the following year these conclusions were questioned by Mr. Meyer, who identified a clay below the thin band of limestone as Atherfield Clay, and expressed his opinion that the "Punfield Beds" of the Isle of Purbeck were Lower Greensand.§ The correctness of this view was placed beyond doubt by his subsequent investigations of the fossils of this clay-bed below the limestone, all of which proved to be well-known Lower Greensand forms, while the shales with Wealden fossils, which were stated to occur above the limestone, were shown to have no existence.

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* *Quart. Journ. Geol. Soc.*, vol. vi., p. 455 (1850).

† *Quart. Journ. Geol. Soc.*, vol. xii., p. 66 (1856).

‡ *Ibid.* vol. xxvii., p. 207 (1871).

§ *Ibid.*, vol. xxviii., p. 243 (1872).

This briefly is the history of the error by which the Lower Greensand of Dorset was correlated with the Upper Wealden of the Isle of Wight under the name of "Punfield Beds." It followed from the mis-correlation that Lower Greensand fossils were recorded as occurring in the Wealden Beds in Dorset, and were

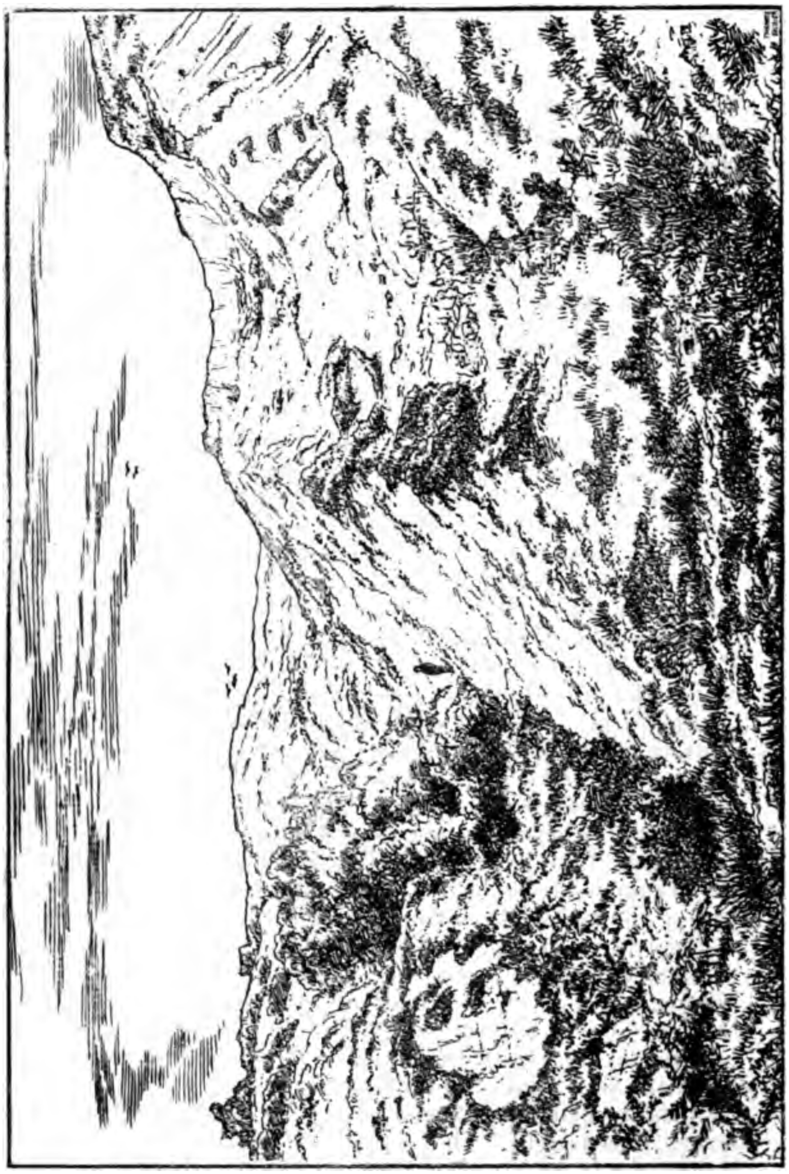

FIG. 138. Junction of the Lower Greensand and Wealden at Punfield Cove, Swanage.

Drawn by H. W. G. Williams from a photograph.

entered in the fossil-lists of that formation, and as a further result it was believed that the Wealden and Lower Greensand were linked together by having in common a number of marked species. Nor was the misconception lessened by the fact that the Wealden had been dissociated from the Purbeck, and placed in a different system (p. 73). As a matter of fact there is not only in the Isle of Wight and in the Isle of Purbeck, but in the south of England generally, a well-defined base to the Lower Greensand, above which, and nowhere below it, occur the characteristic and purely marine species of that formation, while the brackish and fresh-water fauna is confined at Punfield, as in the Isle of Wight, to the upper zone of the Wealden group.

Punfield.

In making the resurvey of the Isle of Wight it became necessary to determine the relations of the "Punfield Beds" of that island to those of Dorset.* The section at Punfield was therefore measured from top to bottom, especial attention being paid to the beds below the thin limestone, in which, if anywhere, an alternation of Wealden and Lower Greensand faunas could have remained undetected. The result of some little excavation was to expose a continuous section of Atherfield Clay, terminating downwards in a conglomeratic base corresponding to the Perna Bed of the Isle of Wight, and resting upon characteristic Wealden Shales with the usual fossils. The alleged mixture of faunas was found to have no existence.

In the accompanying illustration (Fig. 138) the position of the outcrop of the Perna Bed is shown by the figure of a man. To the left is an overgrown bank composed of Wealden Shales, while to the right of the figure a ridge descending the cliff obliquely marks the outcrop of the hard sandstones in the Atherfield Clay. Further to the right again is seen the thin limestone. The strata dip at a high angle from left to right.

Section of the Lower Greensand at Punfield Cove, Swanage.

Gault. (*See* p. 149).		Ft.	In.
Carstone (?), Sandrock Beds, and Ferruginous Sands. 149 feet 2 inches.	Carstone, seen only in lumps lying about; a hard irony grit with pebbles up to half-an-inch in length, apparently about ...	0	4
	Yellow sand, not well seen, about	10	0
	Very sandy dark clay with selenite (perhaps corresponding to the thick clay of Blackgang, in the Isle of Wight)	15	0
	White sandstone with white quartz-pebbles	20	0
	Brown sandstone and yellow sandstone with shales	15	0
	Interlaminated sands and clays, the latter traversed by numbers of small tubes filled with sand (? worm-burrows)	15	0
	Ferruginous sand and hard irony sandstone with *Leda* (*Nuculana*)	12	0
	Interlaminated sands and clay with some thicker beds of yellow and white sand ...	61	0
	Limestone with wavy seams of lignite and many fossils (the "Marine Bed" of Professor Judd); variable, but about ...	0	10

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* "Geology of the Isle of Wight" (Memoirs of the Geological Survey), 2nd Ed. p. 37 (1889).

			Ft.	In.
Atherfield Clay 69 feet 3 inches.		Reddish clay, becoming pale-blue below, and very fossiliferous in the lower part ...	28	0
		Soft yellow sandstone with a few fossils ...	1	0
		Pale-red clay, bluish in parts; a few fossils	8	6
		Four bands of very hard grey sandstone; no fossils	2	9
		Red clay; a few fossils in the lower part ...	6	0
	Perna Bed.	Dark-green sand, with small pebbles and grit; many fossils	1	0
		Pale-blue sandy clay with many small pebbles (rolled bivalves, ammonites, &c.), and larger pebbles of sandstone, wood, &c., at the base; many fossils	2	0
Wealden Shales. (*See* p. 125).			198	5

Though greatly attenuated the subdivisions of the Lower Greensand of the Isle of Wight are therefore partly recognisable at Punfield. In Compton Bay, the westernmost exposure in the Island, the Carstone consists of six feet of brown grit with pebbles of quartzite, phosphates, and bits of wood at its base, the whole corresponding in character to the loose blocks found at this horizon at Punfield. In the same part of the island the Sandrock Beds are composed in the upper part of sands with a few quartz-pebbles, and sometimes brightly coloured, and of interlaminated sand and clay in the lower part, while the Ferruginous Sands include clayey grit, dark-green sands full of glauconite, interlaminated sands and clays, and ferruginous sandstone with many round grains coated by iron-oxide, the two subdivisions together reaching a thickness of 333 feet. At Punfield we have sands, clayey grit, and interlaminated sands and clays in a corresponding position, but reduced to less than half the thickness. The thin fossiliferous limestone, for which the name "marine band" is not distinctive, inasmuch as it constitutes a part of a wholly marine formation, corresponds in position with the Crackers, the most fossiliferous zone in the Atherfield section in the Isle of Wight. Below it lies a clay which differs in no way from the Atherfield Clay, except in being tinged with red in parts and in containing some thin bands of sandstone, the uppermost of which however contains *Arca Raulini*, Leym., *Exogyra*, *Panopæa plicata*, Sow., and *Solecurtus*, all Atherfield Clay forms.

The Perna Bed, which was so named by Fitton from the occurrence in it of *Perna Mulleti* at Atherfield, is there a brown calcareous grit, highly fossiliferous, and always contains scattered pebbles, some of which are rolled Ammonites or other marine fossils; it rests upon a slightly eroded surface of Wealden Shales. At Punfield a highly fossiliferous grit, displaying the conglomeratic character of the Perna Bed, occupies a corresponding position at the base of the Atherfield Clay, and also rests on a disturbed surface of Wealden Shales. Among the pebbles in it there occurred one about two inches long of silicified wood, much resembling the wood of the Lower Purbeck beds.

Lower Greensand Fossils.

Fig. 139.

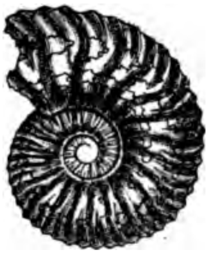

Fig. 140.

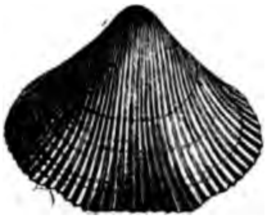

Fig. 141.

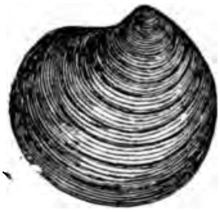

Fig. 142.

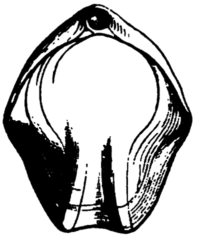

Fig. 144.

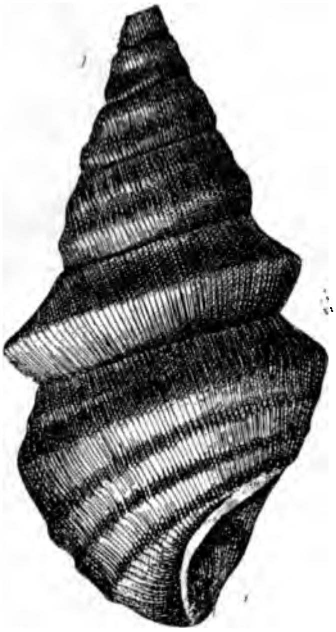

Fig. 143.

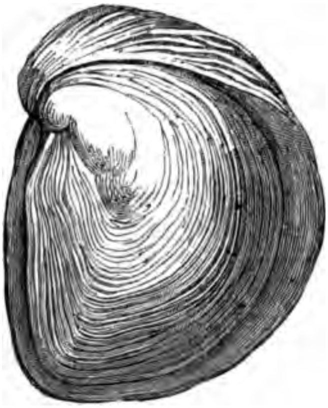

Fig. 139. *Ammonites Deshayesi*, Leym. Small example.
, 140. *Rhynchonella latissima* (Faringdon), Sow.
„ 141. *Lucina dupiniana*, d'Orb.
„ 142. *Terebratula sella*, Sow.
„ 143. *Exogyra sinuata*, Sow.
, 144. *Vicarya pizcuetana*, Vil. Large example ; Nat. size.

Lower Greensand Fossils.

FIG. 145.

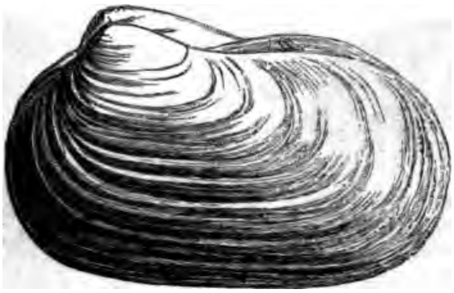

FIG. 146.

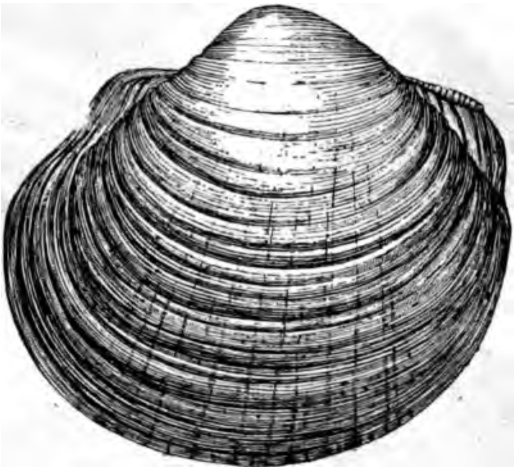

FIG. 147.

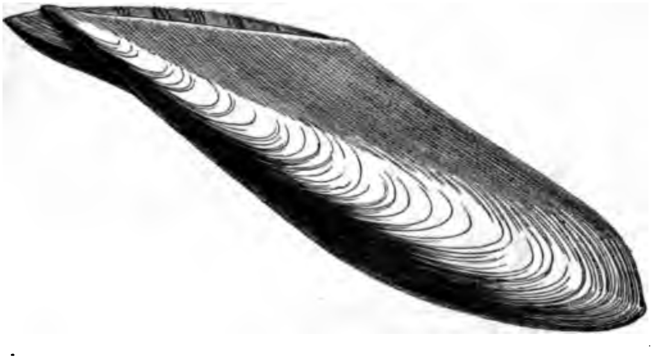

FIG. 145. *Panopæa plicata*, Sow.
,, 146. *Corbis corrugata*, Sow. × ¾.
147. *Gervillia anceps*, Desh. × ½.

Corfe Castle.

The next section of the Lower Greensand was opened in a cutting for the Goods Yard at Corfe Castle Station. The details of the section given on p. 126 were obtained by John Rhodes after removing a part of the grass and soil of the bank, for which permission was kindly given by the Railway Company. The Lower Greensand was exposed to a thickness of 169 feet without reaching its top. In the upper part it was composed of variegated sands as at Punfield. At the horizon of the limestone of Punfield there occurred a band packed with shell-fragments and lignite, below which came a pink clay, blue and buff below, which corresponds to the Atherfield Clay. At the base of all a band of pebbly ironstone with black pebbles, fish-teeth, &c., represents the conglomeratic Perna Bed. The variegated sands are better seen in a road-cutting between Sandy Hill and Corfe, where they are white with bands of crimson.

The shelly bed alluded to above contained *Astarte laticosta*, Desh., *Cardita*, *Cardium subhillanum*, Leym., *C.* sp., *Corbula*, *Cyprina*, *Gervillia*, *Lucina*, *Ostrea*, *Panopæa*, *Tellina inæqualis*, Sow., *Cerithium*, *Natica*, *Rostellaria*, *Scalaria*, *Trochus*, *Turritella*, *Vicarya pizcuetana*, Vil., and *V. strombiformis*, Schloth. The pebbly ironstone or Perna Bed yielded *Cardium subhillanum*, Leym., *C.* sp., *Cucullæa*, *Pecten quadricostatus*, Sow., *P. quinquecostatus*, Sow., *Pholadomya* allied to *Martini*, *Thetis Sowerbyi*, Röm., *Trigonia Etheridgei*, Lyc., *Natica*, *Turritella*, and *Lepidotus* (? derived). A large *Corbis* (? *C. corrugata*), is recorded from this section by Mr. W. H. Hudleston (*Proc. Geol. Assoc.*, vol. xiv., p. 313).

Worbarrow Bay.

The Worbarrow section gives a nearly complete view of all the Cretaceous rocks from the Upper Chalk downwards, excepting some of the soft middle beds of the Lower Greensand, which at the present time are hidden by talus. The lodging of the talus is due to a ridge formed of some ironstone and ferruginous clays which occur at the base of the formation. The section follows:—

Section of the Lower Greensand at Worbarrow.

		Ft.	In.
Gault (*see* p. 151) passing down into			
Basement bed; a brown gritty clay containing pebbles of quartzite half an inch in diameter, flattish concretions with crustacea, and pebbles of fossil wood		1	0
A marked line of erosion.			
Lower Greensand	Grey sand	1	0
	Do. interlaminated with blue clay	2	6
	Grey sand	4	6
	Darker loamy sand	8	0
	Dark-blue sandy clay	6	0
	Grey loamy sand with clay; base not seen... ...	2	0
	Beds not seen	28	0
	Do., do., but pink and white sand visible here and there	50	0
	Grey sand, top not seen	1	0

		Ft.	in
Lower Greensand (*continued*)	Layer of hard ironstone with large *Vicarya* and many other fossils and lignite. This band perhaps corresponds to the limestone of Punfield; it forms a dip-slope on the north side of the ridge mentioned above	0	3
	Grey clays with fossils in concretionary iron-ore, layers of sand, much lignite, probably the representative of the Atherfield Clay	26	0
	Grey sand-rock with lignite	3	0
	Irregular mass of ironstone, passing down	1	6
	Greyish-blue clay with *Cardium* and other fossils and lignite	2	0
		136	9

Wealden Beds. (*See* p. 127.)

In this section we find a basement-bed to the Gault which closely resembles the Carstone of the western parts of the Isle of Wight. Like it, this band passes imperceptibly up into the Gault, but at Worbarrow it rests on a markedly eroded surface of Lower Greensand. Further west we shall find that this plane of erosion becomes more conspicuous, and that eventually the Gault with this ferruginous conglomerate at its base passes quite unconformably on to the Oolitic rocks. If we are right in supposing that the Carstone of Worbarrow and the Carstone of the Isle of Wight are the same, this evidence confirms views formerly expressed,[*] that the true base of the Gault should be taken at the base of the Carstone of the Isle of Wight and not above it, and at a corresponding horizon on the mainland.

The limestone of Punfield, and its supposed equivalent, the shelly bed at Corfe Castle, seem to be represented by a thin layer of fossiliferous ironstone, the replacement of carbonate of lime by iron-oxide being of common occurrence in both Wealden and Lower Greensand. Both the Atherfield Clay and the Perna Bed are much changed in character, and the Wealden Shales are absent, so that we have difficulty in finding the true base of the Lower Greensand, but the fossils of the greyish-blue clay in the above section enable us to include that bed at least in the marine formation.

The ironstone mentioned above contains *Astarte*, *Cardium*, *Corbula striatula*, Sow., *Corbis*, *Crassatella cornueliana* (?) D'Orb., *Cucullœa*, *Lima*, *Modiola*, *Ostrea*, *Pecten*, *Cerithium*, *Rostellaria*, *Turritella granulata*, Sow.[†] Copious chalybeate springs burst out from about the middle of the Lower Greensand on the beach.

Mupe Bay.

At Mupe Bay the difficulties are increased by a mass of chalk-talus, which effectually conceals the junction of the Lower

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[*] "Geology of the Isle of Wight" (Memoirs of the Geological Survey), 2nd Ed., pp. 52-54.

[†] The specimens were identified by Messrs. G. Sharman and E. T. Newton.

Greensand and Wealden Beds. The following section was taken in the upper part of the cliff:—

Section of the Lower Greensand at Mupe Bay.

		Ft.	In.
Gault. (*See* p. 151.)			
Lower Greensand	Light-grey clay with clay-ironstone 3 feet from the top	14	0
	Light-grey clay, interlaminated with white sand; ferruginous concretions and much lignite ...	0	6
	Yellow sandy clay or fuller's earth	0	6
	Bright-yellow and white sand (on the beach below a coal-black carbonaceous sand occurs in the upper part)	18	0
	Blue clay with sandy partings and much lignite ...	4	0
	Sandy clay	9	0
	Beds not seen	20	0
Wealden Beds; mottled clay.			

In identifying the Lower Greensand in this section reliance was placed, in the absence of fossils, upon the lithological resemblance of the bright-coloured sands and interlaminated sand and clay to those of Worbarrow. It will be noticed that the formation cannot exceed 66 feet in thickness, and may be less. It is not seen again in Dorset west of this bay.

Lower Greensand Fossils.

(1) From the Atherfield Clay and beds above it.

Except where otherwise stated, the specimens were collected by J. Rhodes during the resurvey of the district, and have been identified by Messrs. G. Sharman and E. T. Newton.

LOCALITIES.

1. Punfield.
2. Corfe Castle.
3. Worbarrow.

Wood, 1
Crustacean, fragment, 1
Serpula, 1*
Terebratula sella, *Sow.*, 1†
Anomia lævigata, *Sow.*, 1, 1†
Arca cornueliana, *D'Orb.*, 1†
„ cymodyce, *H. Coquand* (*young*), 1*
„ Raulini, *Leym.*, 1., 1†
„ sp., 1
Astarte, 1, 1*, 1†, 3
„ laticosta, *Desh.*, 2
Cardita neocomiensis, *D'Orb.*, 1†
„ sp., 2
Cardium (Arca) Austeni, *Forbes*, 1†
„ impressum, *Desh.*, 1*, 1†
„ subhillanum, *Leym.*, 1, 2
Corbis, 3
Corbula striatula, *Sow.* 1 (?), 3
„ sp. 1†, 2, 3
Crassatella cornueliana (?), *D'Orb.*, 3
Cucullæa, 3
Cyprina, 1†, 2
Cytherea parva, *Sow.*, 1†
Exogyra Boussingaultii, *D'Orb.*, 1*, 1†
„ sinuata, *Sow.*, 1*, 1†
„ tombeckiana, *D'Orb.*, 1†
Gervillia, 2, 3
Isocardia nasuta, *H. Coq.*, 1*
„ sp., 1*
Leda (Nuculana) scaphoides, *P. and C.*, 1*
Lima sp., 1, 3
Lucina sp., 1, 2

---

* Added on the strength of its having been recorded from the "Marine Bands of Punfield" by Prof. Judd, in the *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 215.

† Added on the authority of Mr. Meyer, *ib.*, vol. xxviii, p. 252, and vol. xxix, p. 72.

Modiola giffreana, *P. and R.*, 1*
„ reversa (?) *Sow.*, 3
„ simplex, *Leym.*, 1†
Orthostoma Verneuili, *Vil.*, 1*
Ostrea Leymerii, *D'Orb.*, 1†
„ 2, 3
Panopæa neocomiensis, *Leym.*, 1†
„ plicata, *Sow.*, 1
„ Prevosti, *Leym.*, 1*
„ sp. (= P. plicata, var. of Atherfield), 1†
„ sp., 2
Pecten (Neithea) neocomiensis, *D'Orb.*, 1†
„ robinaldinus, *D'Orb.*, 1†
„ sp., 1†
„ sp., 3
„ sp., 1* (very small)
Perna rauliniana, *P. and R.*, 1*
Pholadomya semicostata, *Ag.*, 1*, 1†
„ sp., 1
Plicatula asperrima, *D'Orb.*, 1*, 1†
„ carteroniana, *D'Orb.*, 1†
Solecurtus Warburtoni, *Forbes*, 1†
„ sp., 1
Tellina (?) gibba, *H. Coq.*, 1*
„ inæqualis, *Sow.*, 2
„ vectiana, *Forbes*, 1†
Thetis lævigata, *D'Orb.*, 1†
Trigonia (Atherfield sp.), 1†
Venus sp., 1†
Actæonella oliviformis, *H. Coq.*, 1*
Actæon Esqueræ, *De Verneuil and De Lorière*, 1*
Actæon pradoana, *De V. and De L.*, 1*
Cerithium Pailleti, *De V. and De L.*, 1*
„ Vilanovæ, *De V. and De L.*, 1*
„ sp., 2, 3
Eulima (?), 3
Fusus (?) neocomiensis, *D'Orb.*, 1*
Natica lævigata, *Desh.*, 1*, 1†
„ pradoana, *Vil.*, 1*
„ sp., 2
Neritopsis minima, *De V. and De L.*, 1*
Pleurotoma Utrillasi, *De V. and De L.*, 1*
Rostellaria, sp., 2, 3
Scalaria, sp., 2
Trochus Esqueræ, *De V. and De L.*, 1*
„ sp., 2
Turritella granulata, *Sow.*, 3
„ Tournali, *H. Coq.*, 1*
„ sp., 2, 3
Vicarya Lujani, *De V. and Coll.*, 1*
„ pizcuetana, *Vil.*, 1, 2, 1*
„ Pradoi, *De V. and De L.*, 1*
„ strombiformis, *Schloth.*, 2
Ammonites Deshayesi, *Leym.*, 1
Lamna (teeth)
Pycnodus (teeth)

(2) From the Perna Bed,

1. Punfield.
2. Corfe Castle.

Multizonopora rimosa, *D'Orb.*, 1
Arca cornueliana (?) *D'Orb.*, 1
„ Raulini, *D'Orb.*, 1
Astarte, sp., 1
Avicula depressa, *Forbes*, 1
Cardita fenestrata, *Forbes*, 1
Cardium subhillanum, *Leym.*, 1, 2
„ sp., 2
Cucullæa, sp., 2
Cypricardia undulata (?), *D'Orb.*, 1
Exogyra subplicata, *Röm.*, 1
Lima lingua (?), *Forbes*, 1
„ sp., 1
Lucina, sp., 1
Panopæa plicata, *Sow.*, 1
Pecten interstriatus (?) *Leym.*, 1
„ quadricostatus, *Sow.*, 2
„ quinquecostatus, *Sow.*, 1, 2
Pholadomya, allied to Martini, 2
Tellina, sp., 1
Thetis Sowerbyi, *Röm.*, 2
Trigonia Etheridgei, *Lyc.*, 2
Lepidotus (? derived), 2

---

* Added on the strength of its having been recorded from the "Marine Bands of Punfield" by Prof. Judd, in the *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 215.

† Added on the authority of Mr. Meyer, *ib.*, vol. xxviii, p. 252, and vol. xxix, p. 73.

CHAPTER XI.—UPPER CRETACEOUS ROCKS.

GAULT AND UPPER GREENSAND.

Introduction.

These formations, which are divided by a merely arbitrary boundary in the Isle of Wight, become inseparable in the district now under description. This results partly from a change in the character of the Gault, in consequence of which it passes westwards into a dark glauconitic sandy clay or silt, so gradually, however, that it is only by a comparison of distant localities that the change can be realised. At the same time the fossils distinctive of the Gault in those districts where it consists of clay almost all disappear, so that both lithological and palæontological evidence is lacking by which to separate it from the Upper Greensand.

Like the rest of the Cretaceous Rocks the Gault and Greensand are thinner in Purbeck than in the Isle of Wight, but unlike the others they thicken again further west, and extend as an important sub-division into Devonshire, far beyond our present district. We shall see also that they are separated from the Lower Cretaceous Rocks by a great unconformity and that they overstep the other Secondary strata in succession until they rest upon the Trias. This break in the middle of the Cretaceous system, though it probably exists elsewhere, acquires prominence here in consequence of the remarkable energy of the earliest of the sets of movements by which the strata near Weymouth have been effected. The earliest movements threw on end all rocks up to and including the Wealden (and probably the Lower Greensand also); the later movements tilted all the strata, including the Tertiary Beds.

Palæontologically these strata are divided by M. Barrois into two zones, characterised respectively by *Pecten asper* and *Ammonites inflatus* (*rostratus*). To the former zone he assigns a thickness of 20 to 23 feet (6 to 7 mètres), and to the latter of 50 to 70 feet (15 to 22 mètres) in the region south of the Hampshire Basin, but there can be little doubt that the lowest zones of the Gault are represented in South Dorset, though none of the characteristic fossils have yet been recorded. Stratigraphically the strata obviously divide themselves into chert-beds above and sands below both in Dorset and the Isle of Wight, but this division does not strictly accord with the zoning mentioned above, for the zone of *Pecten asper* extends some few feet below the chert-beds. A calcareous grit which forms the top of the Upper Greensand, and is regarded by Mr. Jukes-Browne as the equivalent of a fossiliferous sand occupying the same position at

Rye Hill near Warminster,* forms a conspicuous feature in Dorset, from Lulworth westwards.

The Gault and Greensand together attain a thickness of about 160 to 170 feet in the eastern and western parts of the district, but seem scarcely to exceed 100 feet in some of the intervening ground.

Lithologically these strata consist principally of quartz-sand, mixed with more or less clay in the lower part, but throughout them are scattered abundant granules of glauconite, together with small imperfect casts of fossils in brown or nearly black phosphate of lime, while extremely irregular bands and lumps of chert form a characteristic feature of the upper division.

Gault Fossils.

FIG. 148.

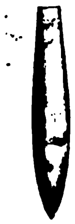

FIG. 149.

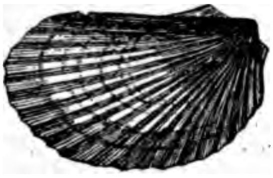

FIG. 151.

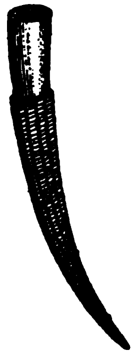

FIG. 150.

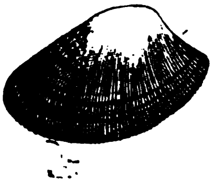

FIG. 148. *Belemnites minimus*, Sow.
„ 149. *Lima parellela*, d'Orb., *non* Sow.
„ 150. *Nucula pectinata*, Sow.
„ 151. *Dentalium decussatum*, Sow.

The origin of the quartz-sand is scarcely determinable in view of the fact that the Gault (or its representative) comes into contact with all the Secondary strata in succession, and must formerly have spread far over Palæozoic and crystalline rocks. The glauconite and phosphate of lime on the contrary were probably formed almost in the positions they now occupy, although their corroded appearance suggests that they are not absolutely in "position of growth."†

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* *Geol. Mag.* 1896, p. 261.

† It should be noted, however, that phosphates of this character are often incrusted by contemporaneous organisms, showing that they lay for some time at the sea bottom before they were buried. Their corroded appearance was probably in part produced while they lay thus exposed.

Upper Greensand Fossils.

FIG. 152

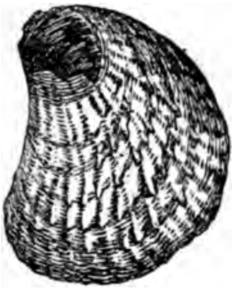


FIG. 153.

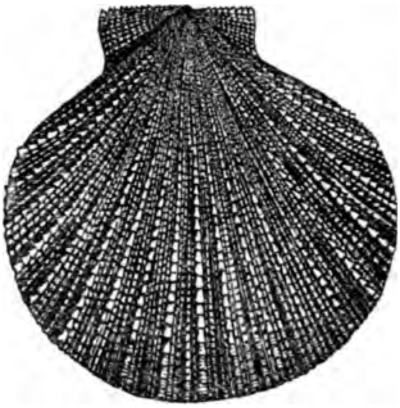


FIG 154

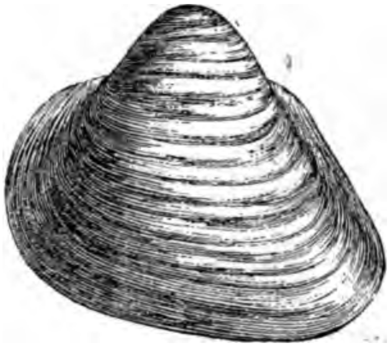


FIG. 155.

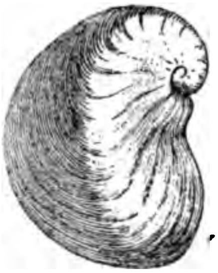


FIG. 156.

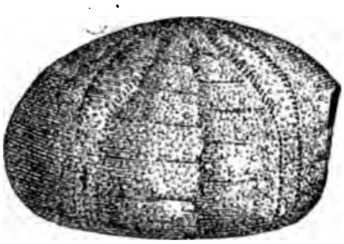


FIG. 157.

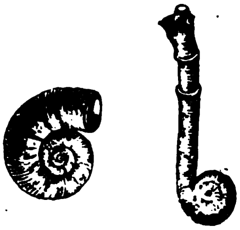
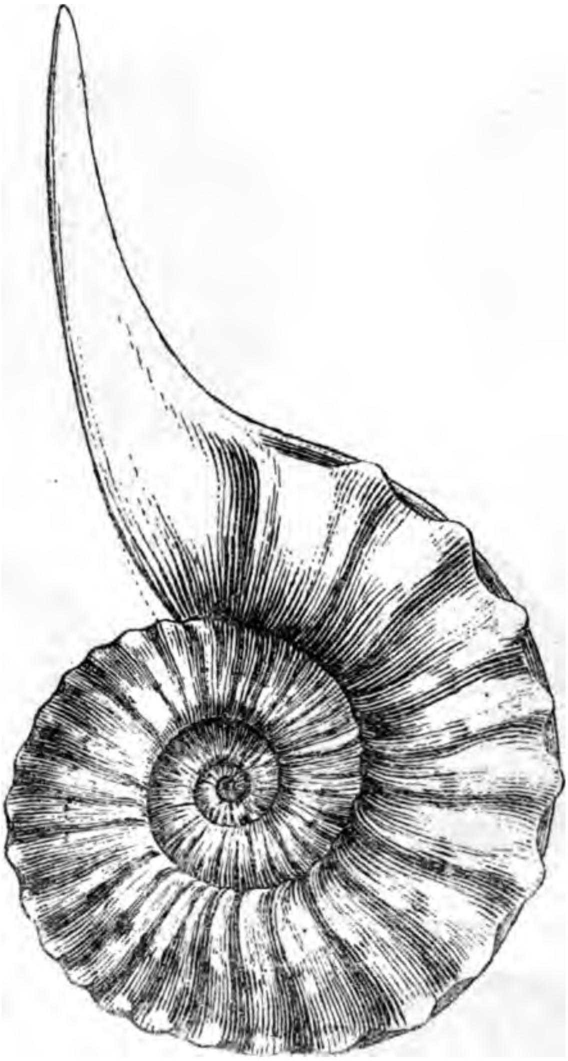


FIG. 152. *Plicatula pectinoides*, Sow.
„ 153. *Pecten asper*, Lam. × ⅔.
„ 154. *Cucullæa glabra*, Park.
„ 155. *Exogyra conica*, Sow.
156 „ ~~155.~~ *Catopygus columbarius*, Lam. (=*carinatus*.)
„ 157. *Vermicularia concava* Sow.

Upper Greensand.

FIG. 158.



Ammonites rostratus, Sow. × ⅓.

The glauconite occurs in granules of irregular shape, but of more or less rounded outlines. Of the infinite variety of forms some resemble the cast of organisms, but a small proportion only can be actually proved to have had this origin: they seem rather to have been formed by concretionary growth.* In this respect they differ from the glauconite in the Chalk and in some calcareous bands of the Lower Greensand, in which they occur principally as an infilling of organic structures.

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* Similar grains from the Lower Greensand are described, and their analysis quoted, in the Memoir on the Isle of Wight, 2nd Ed., p. 255. See also W. J. Sollas on the glauconite of the Cambridge Greensand, *Geol. Mag.* for 1876, p. 539.

The phosphates, on the other hand, are usually recognisable as the casts of fossils proper to the Upper Greensand. Notwithstanding their imperfection, therefore, and their more or less rounded or corroded appearance, they cannot be regarded as derived. At the same time their condition and the absence of the shell indicate that they are not in the same surroundings as when they were formed.

The Upper Greensand, as presented to our view in quarries and even cliff-sections, probably differs much from the rock in a perfectly unweathered condition. It always shews such want of coherence, except in the cherty layers, as results from the decalcification of a calcareous sandstone, and may be compared in this respect to the loose white sand into which some sandy Purbeck limestones pass at their outcrop, or to the brown friable sandstone which results from the weathering of the grey granite-hard Spilsby sandstone. That lime has been removed is proved by the fact that many of the shells are represented by empty moulds in sand, while others have been converted into chalcedony, as in the beautiful Blackdown fossils. One of the consequences of the removal of the lime has been that the glauconite-granules and phosphatic casts have been denuded of their original calcareous surroundings and left lying loose among the quartz-grains. A perfectly fresh specimen of the rock would probably show that both these constituents occur as parts of a crystalline and organic matrix, and have not been transported with the quartz-sand as sediments. Glauconite and phosphate of lime are forming at the sea-bottom at the present day under suitable conditions of depth, temperature, &c., and are frequently associated. The former occurs most plentifully in depths of 200-300 fathoms, and in the neighbourhood of coasts where no rivers enter the sea and where sedimentation is not rapid.* Such may have been the nature of the shore of Palæozoic Rocks along which the Upper Greensand was laid down. The occurrence of glauconite-granules in the chert confirms the view that the former was a contemporaneous product of the Upper Greensand sea, in so far that it proves that it was formed before the silicification of the sponge-beds.

The chert, as has been shown by Dr. Hinde,† consists of innumerable multitudes of the detached microscopic spicules of siliceous sponges. The spicules occur also in the quartz-sands below the chert beds,‡ but do not there form well-defined sponge beds. In describing the mineralisation of the spicules Dr. Hinde observes that in some the silica "yet retains its original colloidal condition, in which it is negative to polarised light, and readily soluble in caustic potash. The matrix of the sponge-beds of the malm and firestone is also to a large extent of colloidal or amorphous silica, and this material has been deposited in the form of minute globules or discs, and it seems to have been derived from the sponge-spicules, with the empty casts of which the beds are throughout filled.

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* Challenger Reports, "Deep Sea Deposits," pp. 382-383.

† *Phil. Trans.*, vol. 176, p. 403 (1885). Plates 40-45.

‡ H. J. Carter, *Ann. Mag. Nat. Hist.*, ser. 4, vol. vii.

"More generally the original amorphous silica of the sponge-remains has been altered to chalcedony, and the chert and porous siliceous rock accompanying it, which is filled with traces of the spicules, are likewise of chalcedony; occasionally the chalcedony gives place to crystalline silica.

"Glauconite very commonly fills the canals of the spicules, and remains after the spicular walls have been removed; it also replaces the spicular walls.

"In some sponge-beds the spicules have been nearly entirely replaced by crystalline calcite; they are imbedded in a matrix of granular limestone.

"As a general rule the sponge-spicules are inclosed in a compact matrix, in which their forms can be only partially studied, but under certain conditions they are loosely distributed in sand or in fine powder in cavities in chert. . . . Entire sponges are absent" (*op. cit.*, p. 448).

A brownish grey chert, which was collected by Mr. Reid from the Upper Greensand of Abbotsbury, presented some marked characters which enabled him to identify the source of some fragments in the Bagshot Beds. The rock encloses numerous empty cavities, and towards the weathered margins becomes so cavernous that the cavities occupy more space than the chert. In this weathered part the silica occurs wholly in the form of small mammillated protuberances of chalcedony, many of which are themselves also hollow. The cavernous condition seems to have resulted from the removal of silica, for no lime occurs in the less weathered parts of the specimen.

Mr. Watts having examined a section of this specimen under the microscope reports as follows:—"No broken fragments of any kind of minerals occur in this rock. It contains the traces of numerous organisms such as sponge-spicules and foraminifera which are now preserved in cryptocrystalline silica, and more silica has gathered round them as radiating masses of chalcedony. In the larger interspaces between the fibrous aggregates thus formed there are more or less imperfect spheres made up of rather coarser crystalline fibres. These have originated round points at the edge of the silica round the organisms, at the edge of one another, or at independent points in the rock.

"In the outer part of the specimen the silica is coloured light-brown and the orbicular bodies of which it consists have a slight agate-like banding. The way in which the relics of organisms are distributed closely resembles that which occurs in limestones, and it is difficult to see how radiating silica can have been formed on all sides of the detached organic bodies unless they were originally imbedded in some soluble substance like calcite. If this is the case the rock may be a silicified limestone. The following events in the history of the rock appear to have occurred, though whether (1) came first or third of the events cannot be determined.

"(1) Preservation or replacement of organisms in cryptocrystalline silica.
"(2) Deposit of fibrous silica round them.
"(3) Further deposit of coarser silica in fibres in the interspaces.
"(4) Solution in great portion of the rock of the organic remains.

"The cavities in the rock have shapes and appearance similar to the organic remains. There are all stages in removal of the cryptocrystalline silica, up to complete loss."

Punfield.

As before, we shall confine ourselves principally to the coast-sections, there being no inland exposures of the Gault, and but few of the Upper Greensand.

Section of the Upper Greensand and Gault a quarter of a mile east of Punfield Cove.

		Ft.	In.
	Chloritic Marl. (*See* p. 167.)		
Upper Greensand about 65 feet.	Greensand with lumps of cherty stone arranged in planes of bedding; a band packed full of *Exogyra conica* about 2 feet from the top. *Siphonia pyriformis*, *Pecten asper*, *P. orbicularis*, *Pleurotomaria*, *Ammonites varians*, abundant in the upper part. This probably represents the Chert Beds of the Isle of Wight ...	6	0
	Green sand; *Pecten quinquecostatus*	18	0
	„ with some bands of lenticular stone	5	0
	„ with a lenticular stone-band in the centre, and with rolled phosphatised bivalves	14	6
	Hard stony band	1	6
	Dark-blue clayey sand with a bright-green streak, becoming darker and more clayey below; hard stony lumps made up of *Vermicularia* and bivalves abundant. Seen at the foot of the cliff to	20	0
Gault.	Beds not seen, but with an estimated thickness of	91	0
		156	0

Of these strata 16½ feet (5 mètres) were assigned by M. Barrois to the zone of *Pecten asper*, and in "green sands and glauconitic clay" beneath, which he placed in the zone of *Ammonites inflatus*, he collected *Serpula tuba*, Sow., *Vermicularia concava*, Sow., *Arca carinata*, Sow., *A. formosa*, Sow., *Panopæa læviuscula*, *Plicatula radiola* (?), Lk., *Pecten laminosus*, Mart., *Janira* [=*Neithea*] *quadricostata*, Sow., *Ostrea columba*, Lk.*

Subsequently the section was minutely examined, and the fossils collected by Mr. H. G. Fordham.† From the uppermost band mentioned in the section of the Greensand given above he obtained:—

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* "Terrain Crétacé Supérieur," 1876, p. 102.
† *Proc. Geol. Assoc.*, vol. iv., p. 506 (1876).

Vermicularia concava, *Sow.*
Terebratella pectita, *Sow.*
Exogyra conica, *Sow.*, var. undata.
„ haliotoidea (?), *Sow.*
Ostrea canaliculata, *D'Orb.*
„ vesiculosa, *Sow.*
Pecten asper, *Lam.*
„ interstriatus (?), *Leym.* [probably Galliennei, *D'Orb.*].
„ orbicularis, *Sow.*
„ quadricostatus, *Sow.*

He also obtained *Cucullæa glabra*, Park, and *Ammonites splendens* [? *varians*], Sow., as casts in brown phosphate.

Below this, from 21 feet of green sand, he collected:—

Serpula annulata, *Dixon.*
„ sp.
Vermicularia concava, *Sow.*
Cidaris (spine)
Exogyra columba, *Sow.*
„ haliotoidea, *Sow.*
Ostrea vesicularis (?), *Sow.*
Pecten interstriatus (?), *Leym.* [probably Galliennei, *D'Orb.*].
„ quadricostatus (?), *Sow.*
Ammonites rostratus, *Sow.*

With these were *Ostrea vesicularis* (?), Sow., *Panopæa plicata*, Sow., and *Trigonia*, as casts in black or brown phosphates.

At about 30 feet below the Chloritic Marl he collected *Rhynchonella compressa*, Lam. [*R. dimidiata*, Sow.], in black phosphate, and at about 37 feet below that bed he got the following list:—

Vermicularia concava, *Sow.*
Exogyra conica, *Sow.*
Ostrea canaliculata, *D'Orb.*
„ vesicularis (?), *Sow.*
Pecten interstriatus (?), *Leym.*

There occurred also *Cucullæa glabra*, Park, *Panopæa plicata*, Sow., *Pecten quadricostatus* Sow., *Trigonia*, sp., in black or brown phosphate.

Below this came a bluish sandy clay, 6 to 14 feet thick, and containing *Vermicularia concava*, underlain by a light-blue continuous stone-band, 1½ feet thick, and containing also *Pecten orbicularis*, Sow., and *Ammonites rostratus*, Sow., together with *Arca mailleana* (?), D'Orb., and *Cucullæa glabra* in black or brown phosphate. This band by his measurement occurs about 55½ feet below the Chloritic Marl, and probably corresponds to the "Hard stony band, 1 ft. 6 in." of the section given above. Underneath it he found a bluish sandy clay, 17½ feet thick, and containing *Vermicularia*, sp., *Exogyra*, sp. (?), *Ostrea*, sp. (?), together with *Arca* (*Cucullæa*) *carinata*, Sow., *Thetis Sowerbyi*, Röm., *Trigonia*, sp., and *Dentalium decussatum*, Sow., in black or brown phosphate. This rested on a stone-band, 2 feet thick, in which there occurred *Plicatula inflata*, Sow., and *Pecten quadricostatus*, Sow. Here, at a depth of about 70 feet below the Chloritic Marl, he draws the line between Upper Greensand

and Gault, at the same time, however, expressing doubt whether it should not be drawn above the bluish sandy clay beds.

The Chert Beds with the same fossils are exposed again east of the spring at Ulwell, and the Gault and Upper Greensand underlie the moat on the south side of Corfe Castle, but are poorly seen. Near Steeple and Tyneham we find little except an occasional projection of chert, until we reach the fine cliff-section of Worbarrow Bay.

Worbarrow Bay.

Section of the Upper Greensand and Gault at Worbarrow Bay.

		Ft.	In.
Chloritic Marl. (*See* p. 176).			
Upper Greensand and Gault.	Sand concreted in irregular lumps	4	8
	Dark green sand, about	3	0
	Lumpy rock, full of *Exogyra conica*, *Pecten asper*, *P. quinquecostatus*, &c.	10	0
	Soft green sand	10	0
	Do. do., with lines of calcareous blocks, full of *Exogyra conica* and *Vermicularia* ...	40	0
	Do. do., but more loamy and getting darker below; a line of phosphatised *Exogyra conica*, *Natica*, *Pleurotomaria*, &c., at 32 feet from top, and layers of stone below	39	0
	Dark-green clayey sand with a few layers of stone, more towards the base; *Lima parallela*, d'Orb *non* Sow., *Pecten orbicularis*, *Natica*, *Aporrhais*	18	0
	Darker and more clayey micaceous sand, or sandy clay, becoming more clayey below, and the lowest 3 feet brown; passing down...	45	0
	Conglomerate of quartzite-pebbles in clay; the supposed Carstone. (*See* p. 139).	1	0
	Marked line of erosion.		
Lower Greensand (p. 139).			
		167	8

The lower portion of these beds corresponds to the Gault as identified at Punfield, but we can draw no hard line between it and the Upper Greensand. The best exposures occur in the upper part of the cliff, but the top of the Upper Greensand is easily accessible on the beach also.

Mupe Bay.

In Mupe Bay the group has apparently lost more than half its thickness. This is doubtless due to squeezing and faulting, which increases in intensity westwards, but it prevents detailed correlation with the section at Worbarrow. Much of the cliff is overspread by talus.

Section of the Upper Greensand and Gault at Mupe Bay.

	Ft.	In.
Chloritic Marl, horizon of the. (*See* p. 177).		
Soft green sand (only the top seen) about	40	0
Green coherent and slightly clayey sand with ferruginous concretions and weathering brown	6	0
Very dark clayey sand, looking like clay	4	0
Dark green loamy sand, weathering brown	13	0
Line of large irony concretions with lignite	0	6
	63	6

On the beach, next below the sandy base of the Chalk, there occur about 21 feet of green sand with a number of apparently rolled phosphatic casts of ammonites and lamellibranchs, among them *Exogyra conica*. This bed rests on a dark-green clayey sand, visible to a thickness of 8 feet. The upper of these two sands somewhat resembles Chloritic Marl, but is, of course, much too thick; the lower of the two, moreover, has no likeness to the chert-beds on which the Chloritic Marl rests at Worbarrow, but compares better with some of the dark sands assigned to the Gault, especially in the section of Lulworth Cove. If it belongs to that part of the group there must be about 80 feet of sand missing between it and the Chalk, probably from squeezing, as before mentioned.

Lulworth Cove.

We now pass on to Lulworth Cove, where a more complete section exhibits details resembling those of Worbarrow Bay.

Section of the Upper Greensand and Gault in the east side of Lulworth Cove

		Ft.	In.
Chloritic Marl.	(*See* p. 178).		
Upper Greensand and Gault.	Sand and brown chert	4	0
	Sand with a few ledges of stone, details obscured	85	0
	Darker sand with *Exogyra conica* and phosphatic casts of *Pleurotomaria*, &c.	12	0
	Darker and more clayey sand, in parts a blue clay; at its base a line of quartzite-pebbles as big as marbles, resting on an eroded surface of	28	0
Wealden Beds.	(*See* p. 129).		
		129	0

The "darker and more clayey sand" of the lower part of this section yields *Cardita*, *Cucullæa carinata*, Sow., *Lima parallela*, d'Orb *non* Sow., *Panopæa plicata*, Sow., *Pecten*, *Pinna tetragona*, Sow., *Dentalium decussatum*, Sow., *Turritella costata*, Sow.

From the east side of the cove the Upper Greensand and Gault pass under the beach to near the landing-place on the west side, throwing out copious springs among the Black Rocks, where their upper boundary coincides with high-water mark. A few yards west of the cove they are faulted out by one of probably many strike-faults which break the sequence of the strata in these promontories, so that Chalk lies in contact with Wealden beds nearly as far as the next bay, west of Dungy Head. There we find the Chloritic Marl three feet thick, much hardened, and with many phosphatic casts, and below it (that is, to the south of it, all being vertical) a very hard white rock, composed of slightly glauconitic sand so closely cemented as to resemble quartzite, three feet thick, and passing down into three feet of green sand, with lumps of white rock as above. Below these come nine feet of hardened green sand, with nodular and tabular chert.

Durdle.

The full sequence can be obtained by combining the observations made on the two sides of the promontory of Durdle

Door. In the following section the chert-beds were measured on the west cliff, and the remainder along the top of the east cliff, in Man-o'-War Cove.

Section of the Upper Greensand and Gault near Durdle Door.

		Ft.	In.
Chloritic Marl. (*See* p. 181).			
Gault and Upper Greensand.	Hard white rock like quartzite (a green sand cemented)	3	0
	Green sand with lumps of rock, as above ...	3	0
	Hardened sand with nodular chert	4	0
	Do. with much chert in irregular masses	2	0
	Dark-green loamy sand	1	0
	Chert and green sand	2	0
	Dark-green sand with three or four bands of cherty stone, *Exogyra conica*, *P. quinquecostatus* and a large *Nautilus*, abundant ...	7	0
	Chert in irregular lumps, and green sand with many fossils	2	0
	[Section continued in Man-o'-War Cove.]		
	Green sand getting darker and more loamy below	84	0
	A conspicuous ferruginous band	1	0
	Dark-blue sandy clay	17	0
	Dark-blue clayey sand	5	0
	Hard white sandstone	0	3 to 6
	Ochry band with quartz-pebbles ranging up to 2 inches in length, but averaging ½-inch (the supposed Carstone)	0	2 to 4
	Strong line of erosion.		
Wealden Beds.			
		131	10

Of these strata the upper 24 feet may be assigned to the chert-beds. The intensely hard white rock at the top makes its first appearance at Durdle, but thence westwards becomes a marked feature. We shall see that it becomes a hard coarse grit inland, repeatedly shewing itself in the hillsides. A conspicuous ferruginous band marks the horizon at which the increasing proportion of clay in the rocks checks the percolation of water. Assuming this to be the top of the Gault, we should have 108 feet for the Upper Greensand and only 23 feet for the Gault, which does not at all agree with their relative thicknesses elsewhere. There is, in fact, no line between the two formations in this part of the country.

A large number of specimens was collected from the Upper Greensand of Durdle and Lulworth by M. Barrois, who made the following measurements.* The section commences at the base of the Chloritic Marl. :—

		Ft.	In.
D20.	White, fine-grained sandstone, slightly glauconitic, with bands of chert ; it becomes quartzose, coarser and less glauconitic upwards	11	6
C19.	Green sand, with many phosphatised fossils ; *Pecten asper*	1	7
18.	Calcareous glauconitic sandstone	1	7
17.	Green marly sand ; fossils in phosphate of lime ...	6	6
B18.	Calcareo-siliceous sandstone ; *Ostrea* ... 9 inches to	1	7
17.	Green sand	1	7
16.	Calcareo-siliceous sandstone, with cavernous surface ...	3	3
15.	Green sand	4	10

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* Terrain Crétacé Supérieur, 1876, pp. 89-92.

		Ft.	In.
B14.	Calcareous sandstone, with large grains of glauconite; *Janira quadricostata* abundant...		
A13.	Sand, with a bed of *Ostrea vesiculosa* at its base; some phosphatised fossils	6	6
12.	Sandstone, with *Serpulæ*	0	7
11.	Green sand	1	7
10.	Bed of small oysters; some phosphatic nodules—*Vermicularia concava*, *Janira quadricostata*, *Plicatula*	0	4
9.	Green sand	6	6
8.	Nodules of calcareous sandstone; many fossils showing a Blackdown relationship	1	7
7.	Dark-grey micaceous sand, with gypsum, pyrites, and small beds of phosphatised fossils—*Vermicularia concava*, *Ostrea vesiculosa*, *Arca*	6	6
6.	Greenish-grey sandstone	0	6
5.	Green sand	29	6
4.	Greyish sandstone—*Vermicularia concava*, *Ostrea conica*	1	7
3.	Sand	3	3
2.	Clayey micaceous sandstone	1	7
1.	Dark sandy clay	1	7
	Do. less sandy (Gault)	13	0

In D. 20 he records the following specimens from Durdle Cove:—

Ostrea carinata
Trigonia
Cidaris vesiculosa, *Goldf.*
„ velifera, *Bronn.*
Caratomus rostratus, *Agas.*

Peltastes clathratus, *Cotteau.*
Catopygus columbarius, *D'Arch.*
Discoidea subuculus, *Klein.*
Holaster nodulosus, *Gold.*
„ suborbicularis ?, *Brong.*

In the same bed in Lulworth Cove he obtained:—

Otodus.
Terebratulina rigida, *Sow.*
Rhynchonella.
Arca mailleana, *D'Orb.*
Cardita dubia, *Sow.* (?)
Pecten near to hispidus, *Gold.*
Janira quadricostata, *Sow.*
Lima archiaciana, *Corn. and Bri.*
„ asteriana, *D'Orb.*
Spondylus Omalii, *D'Arch.*

Ostrea conica, *Lamk.*
Ostrea visiculosa, *Sow.*
Inoceramus.
Cidaris velifera, *Bronn.*
Holaster nodulosus, *Gold.*
Cardiaster fossarius, *Forbes* (?)
Discoidea subuculus, *Klein.*
Glyphocyphus radiatus, *Desor* (?)
Catopygus columbarius, *d'Arch.*
Serpula.

From C. 17 he records:—

Ancyloceras.
Scaphites æqualis, *Sow.*
Rostellaria.
Avellana cassis, *D'Orb.*
Terebratella pectita, *Sow.*
Arca echinata, *D'Orb.*
„ passyana, *D'Orb.*
Trigonia scabra, *Lamk.*
Cardita dubia, *Sow.* ?
Cardium ventricosum, *D'Orb.*
Venus rotomagensis, *D'Orb.* (?)
Cyprina consobrina, *D'Orb.*
Inoceramus.

Janira quadricostata, *Sow.*
Spondylus? (Avicula) occultus, *Gein.*
Pecten asper, *Lamk.*
„ elongatus, *Lamk.*
Ostrea vesiculosa, *Sow.*
„ conica, *Sow.*
Serpula [Ditrupa] difforme, *Dix.*
„ gordialis, *Schl.*
Vermicularia concava, *Sow.*
Discoidea subuculus, *Klein.*
Catopygus.
Holaster Brongniarti ? *(Héb. and Mun-Chal).*

From B 16 he collected:—

Vermicularia concava, *Sow.*
Panopæa læviuscula (?)
Venus.
Plicatula pectinoides, *Sow.*
Janira quadricostata, *Sow.*

Pecten laminosus, *Mant.*
„ hispidus, *Gold.*
Ostrea conica.
„ vesiculosa, *Sow.*
Cidaris vesiculosa ?, *Gold.*

From A. 8 he gives the following list, with the remark that the fauna is that of Blackdown :—

Vermicularia concava, *Sow.*
„ polygonalis, *Sow.*
Holaster (plates)
Pseudodiadema (spines).
Arca equilateralis, *Corn. and Briart.*
„ carinata, *Sow.*
„ formosa, *Sow.*
„ glabra, *Park.*
„ nana, *D'Orb.*
„ obesa, *Pictet and Roux.*
Astarte concinna, *Sow.*
„ impolita, *Sow.*
„ striata, *Sow.*
„ sp.
Cardita dupiniana, *D'Orb.*
Cytherea caperata, *Sow.*
„ parva, *Sow.*
„ subrotunda, *Sow.*
Inoceramus sulcatus, *Park.*
Janira æquicostata, *D'Orb.*
„ quadricostata, *Sow.*
„ quinquecostata, *Sow.*
Limopsis Loriolii, *Renv.*
Mactra ? angulata, *Sow.*
Modiola reversa, *Sow.*
Nucula sp. allied to bivirgata, *Sow.*
Nucula sp. allied to lineata, *Fitt.*
Ostrea canaliculata, *Defr.*
„ conica, *Sow.*
Panopæa Rhodani, *Pict. and Roux.*
Pecten Galliennei, *D'Orb.*
„ laminosus, *Mant.*
„ Milleri, *Fitt.*
Siliqua moreana, *D'Orb.*
Thetis genevensis, *Pict. and Roux.*
„ major, *Sow.*
Trigonia alæformis, *Park.*
„ pyrrha, *D'Orb.*
„ spinosa, *Park.*
„ nov. sp.
Venus faba, *Sow.*
„ immersa, *Sow.*
„ submersa, *Sow.*
„ truncata, *Sow.*
Rostellaria Parkinsoni, *Sow.*
Ammonites crenatus, *Fitt.*
„ Goodhalli, *Sow.*
„ inflatus, *Sow.*
„ raulinianus, *D'Orb.*
„ rostratus, *Sow.* [*Pictet.*
„ sp. allied to varicosus,
Hamites alternatus, *Mant.*
„ virgulatus, *Brong.*

The fauna from D is regarded by him as being that of the Warminster Beds, and the fauna of the strata below as being that of the Blackdown Beds.

White Nothe.

The Upper Greensand and Gault appear next in the great cliff-section of White Nothe. The Chert Beds project as a small bench into the sea at the southern extremity of the point, and the Chalk Marl forms the lower part of the cliff above.

White Nothe, southern extremity.

		Ft.
Lower Chalk.	Evenly-bedded alternations of smooth white chalk and marl with three lines of flints ...	40—45
Chloritic Marl.	Very chalky	3
Upper Greensand and Gault.	Cherty and lumpy rock	6
	Sand with nodules of chert	3
	Sand with nodules and two layers of chert ...	4
	Dark-green sand with cherty lumps. *Pecten quinquecostatus*, *P. asper*, *Discoidea* ...	
	(Section continued 500 yards west of the Coastguard Station.)	
	Dark-green sand—the bed last mentioned above	6
	Green sand with layers of stone	25
	Do. do.	20
	Dark clayey green sand with stone-bands, about	35
	Blue clay, not clearly seen	

Another section a short distance further west gives a magnificent view of the base of the Upper Cretaceous Rocks and of their unconformable superposition upon Oolitic strata. The junction can be identified at once in the brow of the cliff at Holworth House, where Gault dipping E.N.E. at 5° passes in quick succession across the edges of Purbeck, Portlandian, and Kimmeridge Clay dipping N. at 25°.[*] Thence it can be followed for about 600 yards southwards, though it becomes less conspicuous from the fact that the Gault Clay there rests upon Kimmeridge Clay.

The accompanying illustration (FIG. 159) shows Portlandian

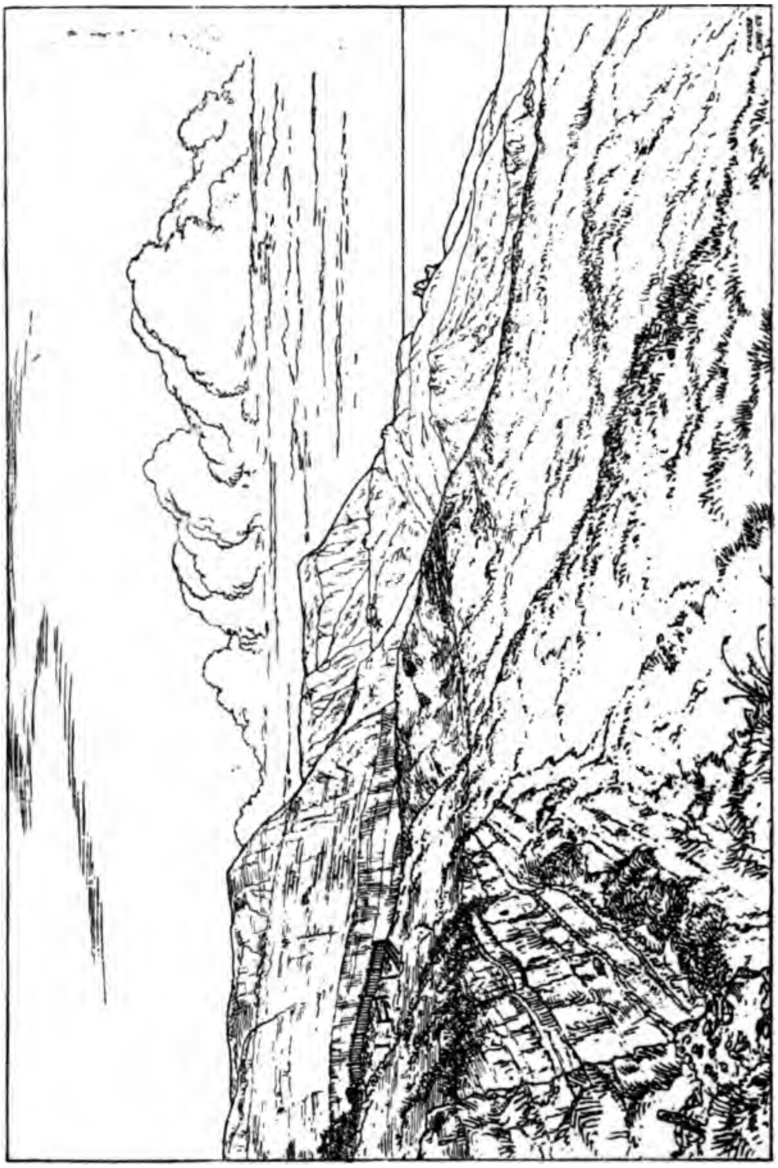

FIG. 159.—Unconformity between Upper Cretaceous and Oolitic Rocks at White Nothe.

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[*] The overlap of the Oolites by the Upper Cretaceous Rocks was first noticed by Buckland and De la Beche (*Trans. Geol. Soc.*, ser. 2, vol. iv., p. 10, 1856). That the Wealden Beds also are overlapped was recorded by the Rev. O. Fisher, who at the same time figured the Holworth section (*Trans. Cambridge Phil. Soc.*, vol. ix., p. 2, 1855).

rocks on the lower left-hand side, with nearly horizontal Gault resting upon them, and in the cliff behind Upper Greensand and Chalk. The furthest point seen is White Nothe with an undercliff of slipped Chalk and Greensand below it. The view has been drawn by Mr. H. W. G. Williams from a photograph.

East of Holworth (or White Nothe) House.

		Ft.	In.
Lower Chalk,	very impure ; a layer of flint at its base ; passing down Chloritic Marl (3 feet thick)		
Upper Greensand and Gault.	Sand with chert in lumps	4	6
	Sand with layers of chert	6	4
	Darker green sand with three layers of stone...	19	0
	do. do. with scattered lumps of stone	13	6
	Irregular layer of stone with *Exogyra conica* abundant	11	0
	Dark-green loamy sand with pipes of clay ...	25	0
	Great lenticular stone-masses	2	0
	Dark sand, as above	13	6
	Great lenticular stone-masses	1	6
	Dark sand, as above ; base not seen	13	6
	Gap.		
	Dark loamy and clayey sand and clay, about	36	0
	Blue sandy and micaceous clay...	4	0
	Thin band containing quartzite-pebbles up to two inches in length, and lumps of Portland Stone up to six inches in length	2	0
	Great Unconformity.		
Kimmeridge Clay	... ...		
		150	0

The following section of the basement-bed of the Gault was taken in the cliff at Holworth House.

		Ft.	In.
Gault.	Blue clay seen up to	2	0
	Ochry brown sand and clayey sand and grit ...	2	6
	Green sand...	5	0
	Thin band containing quartzite-pebbles and lumps of chert...		
	Great Unconformity.		
Portland Stone.	Limestone, piped, and here and there converted into ochre		

The following specimens have been collected here by J. Rhodes, and identified by Messrs. G. Sharman and E. T. Newton:—

Upper Greensand of White Nothe—Chert Beds.

Sponges. (Siphonia, a common upper Greensand form, is recorded by Damon, *Geol. of Weymouth*, 1884, p. 130.)
Discoidea subuculus, *Klein.*
Pseudodiadema variolare, *Ag.*
Serpula antiquata, *Sow.*
„ ilium, *Sow.*
Vermicularia concava, *Sow.*
Cucullæa glabra, *Park.*
Exogyra conica, *Sow.*
Pecten asper, *Lam.*
„ orbicularis, *Sow.*
„ (Neithea) quadricostatus, *Sow.*
„ (Neithea) quinquecostatus, *Sow.*
Trigonia scabriculus, *Lye.*
Natica Gentii, *Sow.*
Ammonites, fragment
Belemnitella
Hamites
Nautilus

Upper Greensand of White Nothe—Sands below the Chert Beds

Vermicularia concava, *Sow.*
Cytherea caperata, *Sow.*
„ plana, *Sow.*
Cucullæa
Exogyra
Panopæa plicata, *Sow.*
Pecten (Neithea) quadricostatus, *Sow.*
Thetis Sowerbyi, *Rom.*
Trigonia
Turritella
Turbo

Gault of White Nothe.

Vermicularia
Arca, fragment
Cucullæa
Exogyra
Lima parallela, *d'Orb.* non *Sow.*
Nucula pectinata, *Sow.*
Panopæa plicata, *Sow.*
Pecten orbicularis, *Sow.*
Pinna tetragona, *Sow.*
Trigonia spinosa, *Park.*
Dentalium decussatum, *Sow.*
Turritella costata, *Sow.*
Fish-scale.

In describing the White Nothe section, M. Barrois states that the Chloritic Marl contains fossils derived from the beds beneath, and places the upper 19 feet of those beds in the zone of *Pecten asper.* In a spot 14½ feet below the Chloritic Marl, but now covered by a landslip, he collected *Serpula* sp. *Ostrea vesiculosa*, Sow., *Pecten asper* (abundant), *Holaster Brongniarti* (?), Hébert, and *Pseudodiadema ornatum*, Desor.[*]

Ringstead and Osmington Mills.

The unconformity at the base of the Gault is again finely exposed for about 50 yards in the brow of the cliff 300 yards west of Osmington Mills. The Kimmeridge Clay dips north at 40°, but the Gault lies horizontally upon it, its base being a loamy buff-coloured sand with an occasional quartz-pebble. In the hill above, the whole of the Gault and Greensand are represented together with the lowest bands of the Chalk, but the last-named has been almost completely decalcified and has mouldered down into a yellow sandy clay, in which, however, the original bedding-places are often distinguishable. In the tract between Osmington Mills and White Nothe, the Upper Cretaceous Rocks are thrown on end by the Ringstead disturbance. The Chert Beds of the Upper Greensand, tilted up at an angle of 75°, project at frequent intervals, but the softer beds are ill exposed.

The following fossils have been recorded by Damon from the Upper Greensand about one mile west of Osmington Mills (Geology of Weymouth, 2nd Ed., p. 130).

†Cardiaster latissimus, *Ag.*
Vermicularia concava, *Sow.*
Astarte impolita, *Sow.*
Cardium hillanum, *Sow.*
Cucullæa glabra, *Park.*
Cypricardia
Cytherea plana, *Sow.*
Exogyra columba, *Lam.*
„ conica, *Sow.*
Inoceramus concentricus, *Park.*
† „ Crispii, ? *Goldf.*
†Janira alpina, *Sow.*
†Lucina dupiniana [? Venus Nystii *Briart and Cornet*]
Modiola
†Panopæa plicata, *Sow.*
Pecten orbicularis, *Sow.*
„ small species
Pectunculus umbonatus, *Sow.*
Trigonia alæformis, *Park.*
Venus, one or two species
†Turritella granulata, *Sow.* (?)
Ammonites, one or two species
Hamites.

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[*] Terrain Crétacé Supérieur, 1876, pp. 78, 79.

† Added to the list, on the authority of Mr. Jukes-Browne, from specimens preserved in the Dorchester Museum.

Chaldon and Ridgeway.

The outcrop of Upper Greensand and Gault along the great Ridgeway disturbance is interesting chiefly from the light it throws on the structure. Though highly inclined, the strata seem to be all represented along the north side of the Chaldon anticline, but at Moigns Down the Upper Greensand and Gault disappear, and Middle Chalk, much disturbed, occurs in close proximity to Purbeck strata; here, therefore, the thrust-plane, described on p. 222, lies between Middle and Lower Chalk. But two miles further west, the Lower Chalk, Upper Greensand, and Gault reappear in proper sequence, and the thrust-plane presumably lies between the Gault and the Oolitic rocks. Just east of Bincombe, they are abruptly faulted out again, but at that village they come in at their proper horizon, and yield the following details:—

Bincombe, 150 yards south-east of the Church.

		Ft.	In.
Chloritic Marl		3	0
Upper Greensand.	Sand with chert in lumps	9	0
	Green sand	0	6
	Brown chert	2	6
	Green sand with a few bands of stone	18	0
	Hardened sand with *Exogyra conica*, *Pecten quinquecostatus*, &c.	3	0
	Soft sand	50	0
	Line of septarian stones	1	0
	Strata concealed	—	

These rocks all dip northwards at 45° to 50°, and have been thrust on to a mass of Oxford Clay, which itself, together with some Cornbrash and Forest Marble, has been thrust on to Portlandian and Kimmeridge Clay (p. 223). Within half a mile this outcrop of Upper Greensand comes to an end, but a brief exposure just east of the Ridgeway Tunnel serves to shew that the upper of the two thrust-planes keeps to pretty nearly the same horizon near Bincombe. Westwards, however, it runs higher up and brings Upper Chalk into contact with the Oolites for several miles.

On the south side of the Chaldon anticline the Upper Cretaceous Rocks are comparatively little disturbed and seem to occur in complete sequence. Some green sands and sandstone near East Chaldon Church yielded *Janira quadricostata*, *J. quinquecostata*, *Ostrea conica*, *Ostrea vesiculosa*, and *Pecten laminosus* to M. Barrois, and were referred by him to the upper part of the zone of *Ammonites inflatus*. The upper part of the Upper Greensand is exposed in numerous places.

Abbotsbury, Long Bredy, and Chilcombe.

The long Ridgeway disturbance comes to an end near Abbotsbury, and the Upper Cretaceous Rocks run along the sinuous Chalk Escarpment without interruption, except in that caused by the subordinate Litton Cheney fault. They rest, however, upon

Oolitic rocks which are largely made up of clay, and their invariable tendency to slip (owing presumably to some part of the Gault still retaining its clayey character) has been so much increased thereby, that the actual ground occupied by them quite misrepresents their real outcrop. Thus both the southern and northern slopes of Abbotsbury Hill present a series of short escarpments of the chert-beds, which are due solely to the slipping of successive slices of those rocks. This *débris* has travelled across the Forest Marble and has partly covered up the outlier of Kimmeridge Clay west of the village. The chert-beds occur at their true horizon in the brow of the narrow gravel-capped plateau of Abbotsbury Castle, and probably have given its characteristic shape to the outlier of the Knoll, though only the underlying sands are now left on that hill. At Gorwell these strata have slipped with unusually little fracturing, and form three successive escarpments, which might easily be mistaken for rock-in-place.

Throughout this part of Dorset the uppermost layer of the Upper Greensand consists of hard calcareous grit, with large grains or even small pebbles of quartz. It ranges from 4 to 10 feet in thickness, and by its conspicuous outcrop in the hill-sides serves to fix the position of the base of the Chalk. It has not been noticed east of Bincombe, unless the hard white quartz grit at Durdle Door represents it.

Long Bredy Hut Lane, which leads up to the Downs between Dowerfield Farm and Long Barrow, passes three sand-pits in the Upper Greensand; the strata dip northwards at 35° and present the following details :—

Near Long Bredy.

	FT.
Calcareous grit, top not seen	1
Soft streaky glauconitic sand with chert	10
Gap.	
Hard nodular green rock with *Exogyra conica*	8
Green sand with nodular rock	10
Soft brown sand with great doggers (seen in the pit on the east side of the road)	30

The calcareous grit, with Chloritic Marl resting upon it, is exposed by the side of the Bridport road at the west end of Chilcombe Hill, and the base of the Gault, so far as can be determined among the landslips, lies about 160 feet below. This is an unusual thickness for the Gault and Upper Greensand in the neighbourhood, but the estimate receives some confirmation in the outlying mass of Shipton Hill. The base of the Gault there occurs at the 400 foot contour, while the hill reaches a height of 559 feet without including any part of the calcareous grit. Allowing 8 feet for the thickness of that rock we may infer that the combined Gault and Greensand are not less than 167 feet thick. A little further east the thickness seems at times scarcely to exceed 100 feet, but at Worbarrow the measurements gave almost exactly the same result. These measurements prepare us for the fact, already alluded to, that the Gault and Greensand, unlike the Chalk, maintain their development, or even increase it, westwards.

CHAPTER XII.—UPPER CRETACEOUS ROCKS.

(Continued.)

CHALK.

Introduction.

The three main sub-divisions of the Chalk which have been recognised through a large part of England can be identified also in South Dorset. They consist in descending order of Upper Chalk which corresponds in some districts, though not here, with the Chalk-with-flints of old authors, and which has for its base a thin nodular band known as the Chalk Rock; Middle Chalk, which in this district also contains flints, and has for its base a poor representative of the Melbourn Rock; and Lower Chalk, also sometimes flinty, with a thick but local bed of white or grey marl near its top. In its lower part the Lower Chalk consists of alternations of chalk and marl, known as the Chalk Marl, and passes downwards into a basement-bed composed of grains of quartz and glauconite and phosphatic casts of fossils embedded in a more or less chalky matrix. This band still passes under the name of Chloritic Marl, a name originally acquired through the glauconite having been wrongly determined as chlorite. Though stratigraphically corresponding to the Chloritic Marl of the Isle of Wight, it is open to doubt whether it is the precise zonal equivalent of that stratum, which is characterised by the siliceous sponge, *Stauronema Carteri*, that fossil not having been observed in South Dorset.*

The highest zone of the Upper Chalk recognised in this district is that of *Belemnitella mucronata*. Upon this, in the eastern part of the area, the Tertiary strata rest with the usual unconformity, but as usual without any obvious want of parallelism in the stratification. Westwards, however, a large part of the Chalk is abruptly and irregularly overlapped by Tertiary gravels, and, as will be shown later on, there is reason to think that the whole of the Cretaceous Rocks must have been denuded from parts of the South-West of England before the expiration of the Eocene period.

Downwards the limit of the Chalk is somewhat sharply defined. Though there is no actual unconformity, stratigraphical or palæontological, between the Chloritic Marl and Upper Greensand, there are generally signs of slight erosion having taken place. The former, in addition to an indigenous fauna of Chalk Marl affinities, contains a number of phosphatised casts with a water-worn aspect which can hardly be due to decalcification in a stratum still rich in lime. Among the fossils thus preserved the majority range up into the Chalk Marl, or are peculiar to the Chloritic Marl, and a few, like *Pecten asper*, *Rh. dimidiata*, var. *convexa*, and *Catopygus carinatus* range downwards only. The condition of the casts, however, leads to the conclusion that they are not strictly *in situ* though their sharpness and partial retention of the shell suggest that they have not travelled far. The break in the sequence of deposits thus indicated is proved by the close palæontological relationship of the top zone of the Upper Greensand (Warminster Beds) and the Chalk Marl to have been of short duration, but at the same time it affected a large area.*

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* A. J. Jukes-Browne and W. Hill, *Quart. Journ. Geol. Soc.*, vol. lii., p. 109 1896).

The probability of many of the phosphatic casts of the Chloritic Marl of South Dorset having been derived did not escape M. Barrois, who definitely states that at White Nothe the top of the Upper Greensand is hardened and corroded, and that in the base of the Chloritic Marl there is a large number of fossils which must have been derived from beds below. An equally marked example of erosion at this horizon occurs at Litton Cheney (p. 190).

FIG. 160.

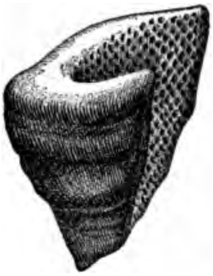

FIG. 161.

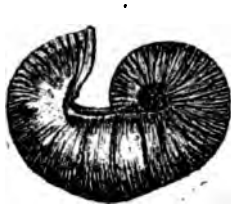

FIG. 160. *Stauronema Carteri*, Sollas. ½.
„ 161. *Scaphites æqualis*, Sow.

From Corfe Castle westwards as far as Bincombe, a distance of about 17 miles, a bed of soft chalk-marl forms a noticeable feature in the top of the Lower Chalk, as observed by Mr. Whitaker.† It occurs nearly, if not exactly, on the horizon of the *Belemnitella*-Marl, and contains the characteristic fossil *Belemnitella plena*. By M. Barrois it was identified as the representative of that band, but though it doubtless belongs to the zone there is some doubt whether it does not lie a few feet lower in the series than the *Belemnitella*-Marl of other parts of England. Neither this band nor the Melbourn Rock have been detected in the faulted escarpment west of Bincombe, or in the somewhat sectionless downs of Long Bredy and Chilcombe. The Chalk Rock, on the other hand, was identified at intervals throughout the whole region by Mr. Whitaker as long ago as 1867.†

The thickness of the Chalk varies from about 1300 feet in the eastern part of the district (Ballard Point) to about 1150 or

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* Fordham, *Proc. Geol. Assoc.*, vol. iv., p. 513 (1876). Jukes-Browne, *Geol. Mag.* 1877, p. 357. *See also* "Geology of the Isle of Wight" (Geol. Survey Mem.), 2nd. Ed. pp. 79-80.

† *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 93 (1871).

Lower Chalk Fossils.

FIG. 165.

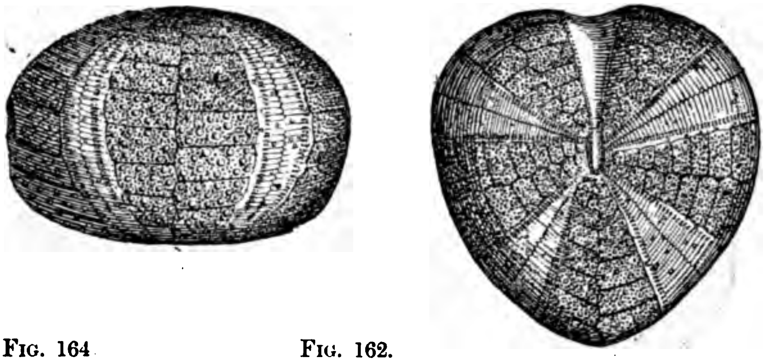

FIG. 164

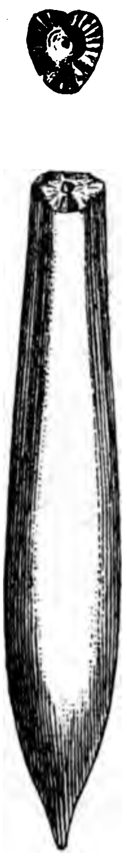

FIG. 162.

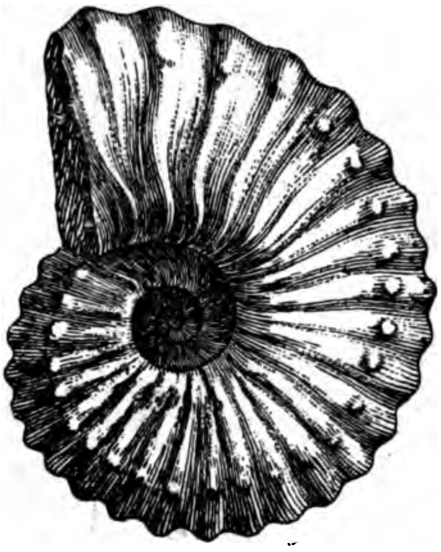

FIG. 166.

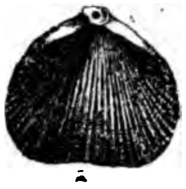

FIG. 163.

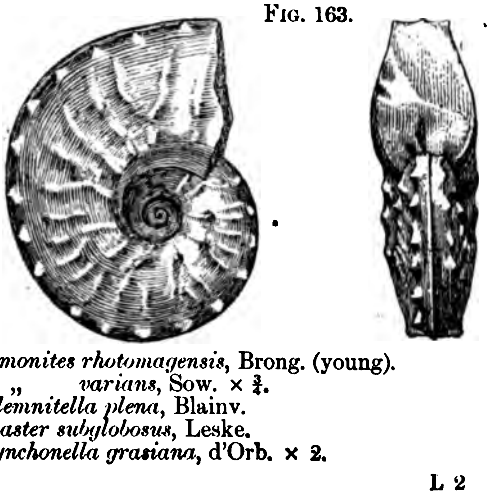

FIG. 162. *Ammonites rhotomagensis*, Brong. (young).
" 163. " *varians*, Sow. × ¾.
" 164. *Bellemnitella plena*, Blainv.
" 165. *Holaster subglobosus*, Leske.
" 166. *Rhynchonella grasiana*, d'Orb. × 2.

1200 feet in the central part (Lulworth), and to about 500 or 600 feet in the western part (Blackdown), but in the last-named a variable thickness of chalk is missing, owing to the unconformable overlap by Tertiary strata. The attenuation westwards is equally noticeable in all three sub-divisions, as shewn in the following table:—

Middle Chalk Fossils.

FIG. 169.

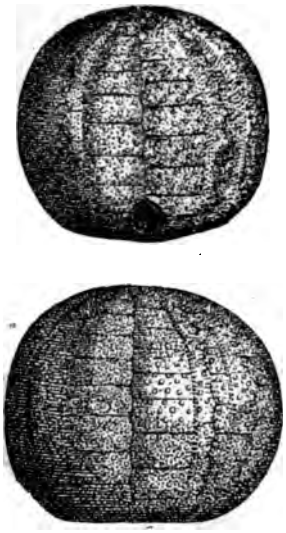

FIG. 167.

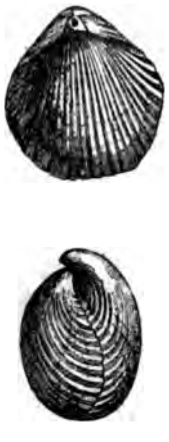

FIG. 170.

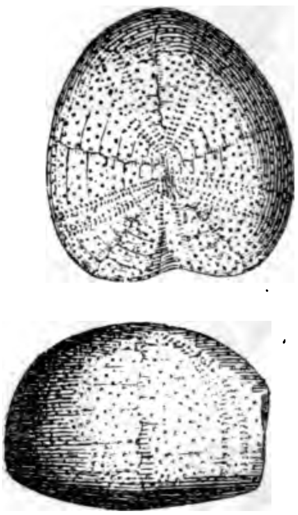

FIG. 171.

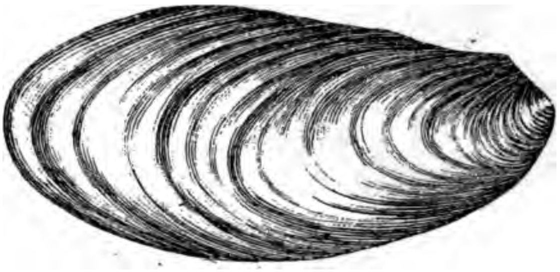

FIG. 168.

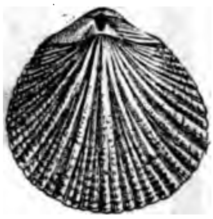

FIG. 167. *Rhynchonella Cuvieri*, d'Orb. × 2.
„ 168. *Terebratulina gracilis*, Schloth. × 3.
„ 169. *Echinoconus subrotundus*, Mant.
„ 170. *Holaster planus*, Mant.
„ 171. *Inoceramus mytiloides*, Mant. × ½.

	Ballard Point.	Worbarrow, Lulworth, and White Nothe.	Black Down and Westwards.
	feet.	feet.	feet.
Upper Chalk ...	1049	956	300 to 500
Middle Chalk ...	102	113 to 90	100 to 150
Lower Chalk ...	149	114 to 104	

Upper Chalk Fossils.

FIG. 175.

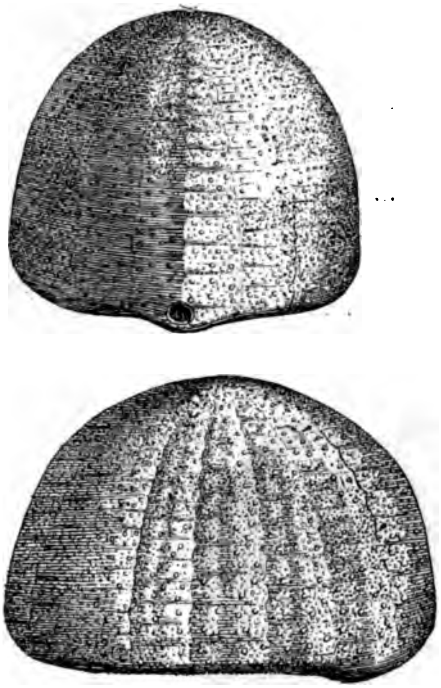

FIG. 174.

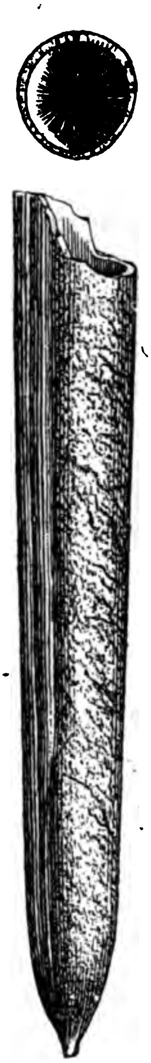

FIG. 172.

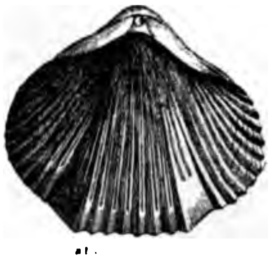

FIG. 173.

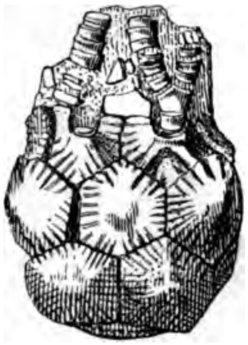

FIG. 172. *Rhynchonella plicatilis* (*var. octoplicata*), Sow. Large example.
„ 173. *Marsupites ornatus*, Miller.
„ 174. *Belemnitella mucronata*, Schloth.
„ 175. *Echinocorys vulgaris*, Breynius. × ¾.

The Palæontological zones into which the Chalk has been sub-divided, and which were identified in South Dorset by M.

Barrois, have been estimated by him to attain the thicknesses shown below:—*

Stratigraphical equivalents in the English classification.	Zonal fossil.	Thickness.	
		Mètres.	Approximate equivalent in feet.
Upper Chalk	Belemnitellæ	30— 50	98 —164
	Marsupites	100—150	328 —492
	Micraster coranguinum ...	35— 40	115 —131
	„ cortestudinarium	30— 40	98 —131
	Holaster planus	3— 7	10 — 23
Middle Chalk	Terebratulina gracilis ...	20— 30	65 — 98
	Inoceramus labiatus ...	15— 20	49 — 65
Lower Chalk	Belemnites plenus ...	1— 3	3 — 10
	Holaster subglobosus ...	10— 30	32 — 98
Chloritic Marl	... ...	0·50—1·50	1½— 5

Upper Chalk.

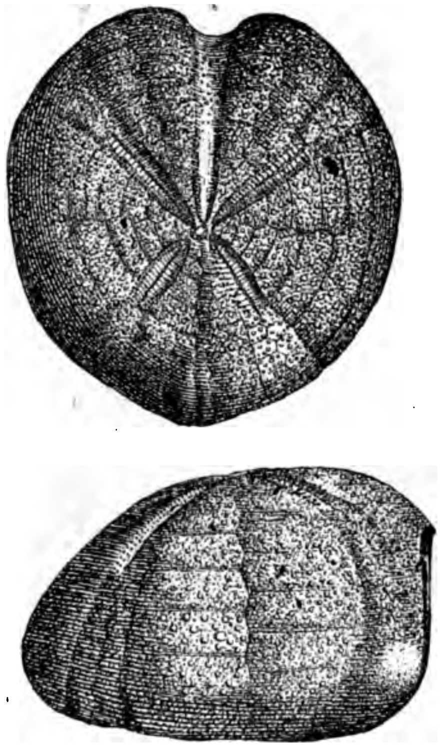

FIG. 176. *Micraster cor-anguinum*, Leske.

Swanage and Studland.

In describing the Chalk it will be necessary to recross the ground already traversed in our account of the Upper Greensand. The localities will be taken in order from east to west as before, and we commence, therefore, with the section of Ballard Cliff and Studland Bay at the point where it was left in Chapter XI.

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* Terrain Crétacé Supérieur, 1876, p. 104.

Ballard Cliff.[*]

			Ft.	In.
Upper Chalk		Chalk with flints		
		Massive but somewhat lumpy chalk, without flints	20	0
		Chalk Rock [†]; a layer of very hard green-coated nodules	0	4
Middle Chalk 102 feet.		Hard, rough, and lumpy chalk	6	0
		Smooth, thick-bedded chalk, with partings of marl	90	0
		Melbourn Rock; rough, nodular, and flaky chalk, with sparry joints	6	0
Lower Chalk 149 ft. 2 in.	Zone of *Belemnitella plena.*	Smooth chalk, with conchoidal fracture, and five partings of pale-blue marl	4	0
		Smooth chalk, passing into	2	0
		Fine marl	5	0
		Alternations of chalk and marl in bands of 1 to 2 feet thickness; an occasional line of green nodules, like those of the Chalk Rock. *Ammonites varians* occurs in the lower 22 feet, but not above [‡]	126	0
		Hard chalk-marl weathering into rhombs	6	0
		Very hard splintery chalk	1	4
		Sandy and glauconitic marl	0	10
		Chloritic Marl; glauconitic sand, with rolled phosphatic casts of *Ammonites*, *Nautili*, and *Exogyræ*, the last apparently indigenous	4	0

Upper Greensand. (*See* p. 149).

These divisions can be readily correlated with those of the Chalk in the Isle of Wight. The lowest layer of flints occurs about 20 feet above the Chalk Rock, in the western end of the Island; the Middle Chalk has much the same aspect, but has lost about one-half its thickness in Dorset; the Melbourn Rock and *Belemnitella*-zone show no changes of importance, except that some alternations of chalk and marl come in above the principal marl-bed, while the Lower Chalk differs only in being more split up by marls in the upper part.

The Chalk Rock descends to the beach on the south side of the headland at the furthest point accessible on foot. The cliff beyond this and Ballard Point consist of intensely hard, flinty chalk, with a dip increasing northwards till the strata become vertical. The rock breaks with a conchoidal fracture and, so far from soiling the fingers as is usual, is hardened into a limestone, and can only be scratched by a knife, while the whole cliff is traversed by veins of calcite and innumerable planes of slickenside (Fig. 177). Under the microscope many perfect foraminifera can be detected, showing that though there has been reconstruction and cementing, the rock has not been perfectly crushed.

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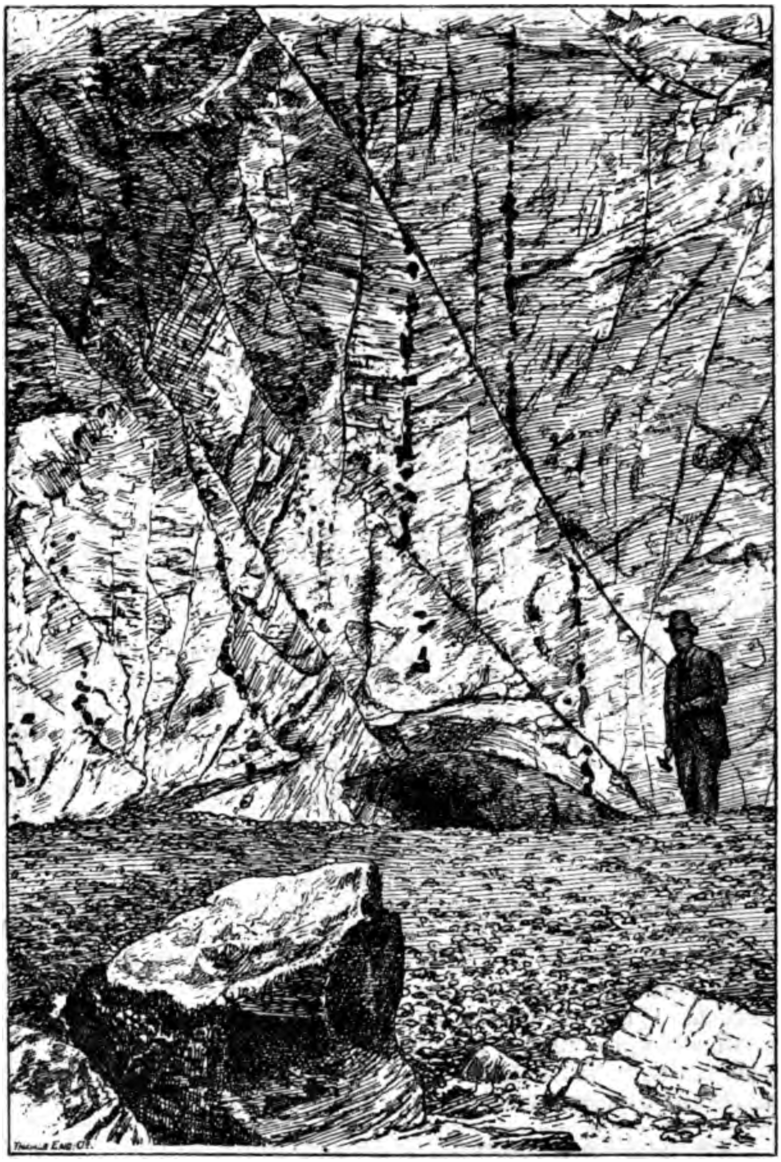
[*] The section differs somewhat from that given in the Memoir on the Isle of Wight, 2nd ed., p. 90. A second visit enabled me to add more details, and at the same time to slightly change the grouping of the strata. The *Belemnitella plena* zone and the Chloritic Marl are now included in the Lower Chalk.

[†] The Chalk Rock is included in the Upper Chalk in this Memoir, as in that on the Isle of Wight. Physically, the base of this hard stratum is the most suitable line to select, but palæontologically the Chalk Rock is at least as closely united to the beds below it as to those above it.

[‡] According to J. Rhodes, fossil-collector to the Geological Survey.

FIG. 177.



Vertical Chalk with flints, Ballard Point. *Drawn by H. W. G. Williams from a photograph.*

M. Barrois remarks that the similar hardened chalk of Corfe Castle closely resembles a rock of the same age which lies beneath the basalt of the north of Ireland, and gives the following analyses, made for him by M. Duvillier:—

Analyses of Chalk from the Zone of Belemnitella mucronata.

	1. Glynn, Ireland. **Hardened and metamorphosed; beds horizontal.**	**2. Studland Bay.** **Soft; beds slightly inclined.**	**3. Corfe Castle.** **Hardened; beds tilted.**
Clay	0·35	0·38	0·42
Soluble silica	0·15	0·11	0·10
Oxide of iron	0·10	0·54	0·28
Phosphate of lime	0·13	0·18	0·26
Carbonate of lime	99·12	97·99	98·17
Carbonate of magnesia	0·13	0·62	0·74
	99·98	99·82	99·97

He suggests that the hardness of the rock may be due, in part, to the larger proportion of carbonate of magnesia which it contains. But the analyses do not support this view, for the soft Studland chalk contains almost as much magnesia as the Corfe Castle rock, and more than the Irish chalk. They serve to show, however, that the chemical composition of the hardened chalk along the line of fault is almost identically the same as that of the chalk which has not been thus altered. The hardening seems to have been due to the rock having been compressed beyond its crushing point, and subsequently cemented by calcite, a process which would leave the chemical composition of the mass unchanged.

From Ballard Point northwards we pass hardened and vertical chalk for 120 feet, and then reach the Isle of Purbeck Thrust-fault, which is perfectly exposed to view from top to bottom of the cliff, here about 250 feet in height. In the immediate neighbourhood of the fault the flint-nodules are not only shattered, but the fragments are shifted, so that, as Webster remarks, what was originally a flint is now represented by a group of shattered splinters. Many small cracks run parallel to the principal fault, and some of them are coated on either side with flint (of later origin of course than the flint-nodules) but have been left hollow in the middle. The fault itself forms a very sharp line, curving upwards in the cliff with beautiful regularity, and keeping exactly parallel to the bedding-planes of the beds above it. These strata curve up through nearly an eighth of a circle, so as to be nearly vertical in the top of the cliff, while at the foot of the cliff they dip northwards at an angle of about 40°. Through the whole curve they rest upon the edges of vertical chalk, with a curiously close imitation of a great unconformity (Plates IV., VII. and XI.). The origin of the structure will be discussed in Chapter XV.

About 70 yards north of the fault the strata become nearly horizontal, and so continue to Handfast Point, where they dip a little west of north at 8°. The alteration of the chalk is much less noticeable in the beds above the fault than in the vertical strata below it, and ceases altogether in the horizontal beds, which shew no disturbance except a few small faults and joints with slickenside. The joints, however, have the effect of causing the cliff to break away into roughly rectangular masses, and give it an appearance which led Webster to compare it to "a work of art, a huge bulwark erected to oppose the force of the sea." Several great columns of chalk, two of which are known as Old Harry and Old Harry's Wife,* stand detached from the parent-cliff, but still preserve a small patch of green-sward on their summits. A much larger mass, now forming the promontory of Handfast Point, is connected with the mainland by an extremely narrow neck, and will, before long, be disconnected.

At this point the cliff trends westwards into Studland Bay. It nearly follows the strike of the beds, and in walking along the beach we keep on the same horizon for upwards of half a mile. Eighty yards beyond some springs of fresh water which burst out in the foreshore below high-water mark, the Tertiary Beds make their appearance in the top of the cliff, and thence slope gradually down to the beach in a further distance of 250 yards. They rest upon a deeply piped surface of chalk, and have at their base a hard brown grit with rolled flints and here and there some red or mottled clay. The following section was taken 60 yards east of the point where the Chalk sinks below the beach :—

Section of the base of the Tertiary strata in Studland Bay.

		FT.
	Flint gravel	6 to 10
Woolwich and Reading beds	White sand	40
	Mottled clay	0 to 6
	Chalk	

M. Barrois recognises the following zones in the cliffs between Punfield and Studland.† The chalk of the cliff in Studland Bay is assigned to the zone of *Belemnitellæ ;* it is by his measurement about 130 feet thick, but there seems to be a considerably greater thickness than this on the south side of the fault, if the base of the zone has been correctly shown on his section (*op. cit.* Fig. 7). It contains black flints, and yields the following fossils :—

Serpula [Ditrupa] deforme, *Dix.*
„ lombricus, *Defr.*
Amorphospongia [Porosphæra] globosa
Cyphosoma elongatum, *Cott.*
Cidaris serrata
Echinocorys
Magas pumilus
Rhynchonella limbata
Rhynchonella octoplicata
„ subplicata, *Mant.*
Inoceramus
Lima Hoperi, *Defr.*
Pecten cretosus, *Defr.* [P. nitidus, *Mant.*]
Spondylus dutempleanus, *D'Orb.*
„ æqualis, *Héb.*
Belemnitella mucronata, *Schlt.*

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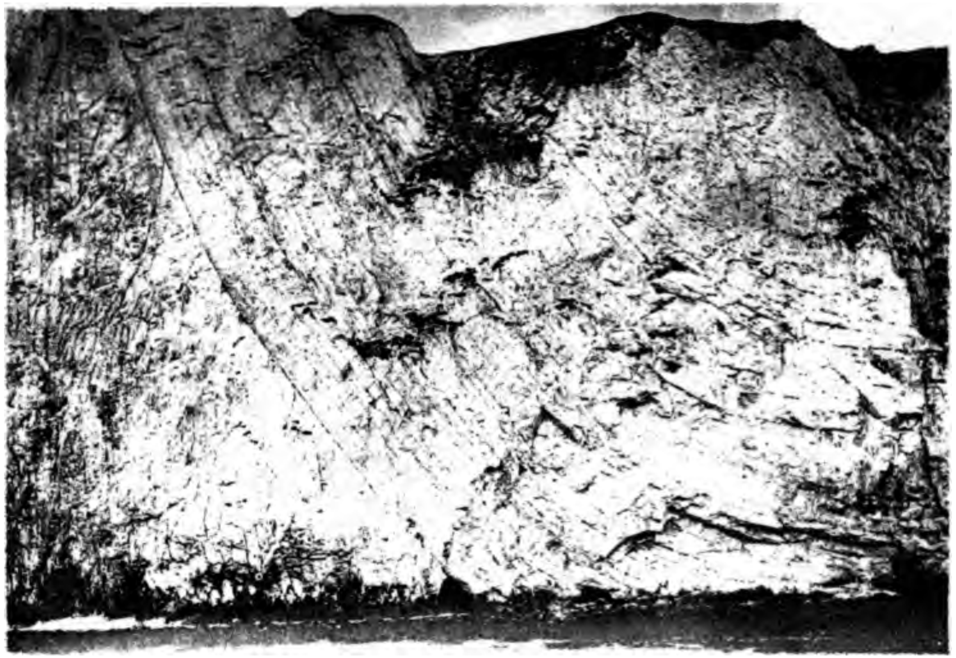
* Destroyed by the sea in 1896, after this description was written.

† "Terrain Crétacé Supérieur," 1876, pp. 101-104.

Plate IV.



THE ISLE OF PURBECK FAULT, BALLARD CLIFF.

9020 8.97

For its base he selects a hardened and eroded band visible in the cliff at Handfast Point (the Foreland). Below it comes the *Marsupites*-zone, which forms the cliff as far as the fault; it contains but little flint. On the south side of the fault he recognised the zone of *Belemnitellæ* in a vertical position, followed again by the *Marsupites*-zone, from which he obtained :—

Amorphospongia [Porosphæra]
Bourgueticrinus ellipticus, *Mill.*
Cidaris
Echinocorys gibbus, *Lk.*
Rhynchonella limbata, *Dav.*
Janira
Asteries

Next in descending order come the zone of *Micraster coranguinum*, the zone of *M. cortestudinarium*, with abundant black flint and about 85 feet thick, and the zone of *Holaster planus*, the last-named being a hard nodular chalk about 17 feet thick with *Micraster breviporus* and *Lima Hoperi*, Defr. The base of this zone coincides approximately with the Chalk Rock of the section on p. 167, and from it and the beds below it the following fossils have been collected by J. Rhodes and identified by Messrs. G. Sharman and E. T. Newton.

Chalk Rock, Ballard Point.

Parasmilia.
Cidaris clavigera, *Konig.*, spines.
Cyphosoma radiatum ? *Sorrig.*
Serpula annulata ? *Reuss.*
Rhynchonella Cuvieri, *d'Orb.*
„ plicatilis, *Sow.*
Terebratula biplicata, *Sow.*
„ semiglobosa, *Sow.*
Terebratulina gracilis, *Schloth.*
Spondylus spinosus, *Sow.*
Spondylus ?
Teredo amphisbæna, *Goldf.*

Middle Chalk.

Porosphæra globularis.
Bourgueticrinus.
Cidaris, spine.
Cyphosoma radiatum, *Sorrig.*
Discoidea subuculus, *Klein.*
Echinoconus subrotundus, *Mant.*
Hemiaster minimus ?, *Ag.*
Micraster breviporus, *Ag.*
Serpula.
Vermicularia.
Cirripede.
Cellepora.
Eschara.
Escharina inelegans, *Lons.*
Rhynchonella Cuvieri, *D'Orb.*
„ plicatilis, *Sow.*
Terebratula carnea ?, *Sow.*
„ semiglobosa, *Sow.*
Terebratulina gracilis, *Schloth.*
„ striata, *Wahl.*
Inoceramus Brongniarti, *Sow.*
„ Cuvieri, *Sow.*
Lima semisulcata, *Sow.*
Ostrea vesicularis, *Lam.*
Spondylus dutempleanus, *D'Orb.*
„ latus, *Sow.*
„ spinosus, *Sow.*
Ammonites Cunningtoni, *Sharpe.*

Lower Chalk (zone of Belemnitella plena).

Rhynchonella plicatilis, *Sow.*
Inoceramus mytiloides ?, *Mant.* (from the Marl Bed).
Inoceramus, sp.
Ammonites rhotomagensis, *Brong.*
Turrilites, fragment.

Lower Chalk (below the zone of B. plena).

Cidaris.
Discoidea cylindrica, *Lam.*
Holaster subglobosus, *Leske.*
„ trecensis, *Leym.*
Rhynchonella plicatilis, *Sow.*
Terebratula.
Inoceramus cuneiformis ?, *D'Orb.*
„ mytiloides ?, *Mant.*
Lima globosa, *Sow.*
Ostrea vesicularis, *Lam.*
Pecten Beaveri, *Sow.*
„ orbicularis, *Sow.*
Ammonites Mantelli, *Sow.*
„ rhotomagensis, *Brong.*
„ varians, *Sow.*
Scaphites æqualis, *Sow.*
Turrilites scheuchzerianus ?, *Bosc.*

The green nodules in the Lower Chalk of Ballard Point were noticed by M. Barrois and were analysed for him by M. Duvillier with the result of showing that they contain nearly 20 per cent. of phosphate of lime:—

Green Nodules from the Lower Chalk, Ballard Hole.

Sand and clay	8·40
Soluble silica	1·14
Oxide of iron	1·96
Phosphate of lime	19·91
Sulphate of lime	0·91
Carbonate of lime	65·62
Carbonate of magnesia ...	0·89
	98·83

M. Barrois, assuming that the distance from the base of the Chalk to the fault was 500 mètres, and that the average dip was 60°, calculated the thickness of Chalk at 433 mètres (about 1,450 feet). He adds that he had not expected to find a thickness of more than 300 mètres (about 1,000 feet), and that he cites this example to show how little reliance can be placed on calculations of this sort, when they are applied to beds with such varying dips. As a matter of fact the distance to the fault is about 400 yards and the average dip is more than 60°, for much of the Chalk is vertical, while the dip of the lower beds ranges from 55° to 60°. The actual thickness of Chalk between the fault and the Upper Greensand as measured at right angles to the bedding on the plotted section (Plate XI.) amounts to 1,175 feet. To this must be added a small part of the Belemnitella-zone which is not seen south of the fault, and a certain allowance for compression. The true thickness is probably not far short of 1,300 feet.

Studland to Worbarrow.

In its course westwards along the Downs the Isle of Purbeck Fault has given rise to a marked feature, for the vertical chalk on its south side stands up in a ridge, while the horizontal or slightly inclined chalk to the north of it forms a dip-slope rising gently from the adjoining Tertiary area. This feature leads to the transverse valley of Ulwell, westward of which the fault throws Tertiary beds against Chalk for several miles.

The spring at Ulwell issues from Chalk Marl, on the east side of the road. Directly in the line of strike of this marl, on the west side of the road, the Melbourn Rock can be identified; a fault therefore with a downthrow to the west must run along the road. A corresponding displacement can be detected in the beds below the Chalk, and by thus fixing several points on the line of the fault we see that it coincides almost exactly with the valley which here obliquely traverses the Downs. Such coincidences are not so common as might have been expected.

On Round Down there are exposures of the flinty chalk and of the nodular chalk which lies next above the Chalk Rock. A lime-pit on the south side shews Chalk Marl, while just above the edge of the pit a hard greenish nodular bed (Melbourn Rock) sticks up through the turf. The road slanting up north-westwards from Knitson passes a pit in which nearly 20 feet of nodular rock belonging to the Middle Chalk are exposed. The Chloritic Marl can be found repeatedly in the bottoms of the old marl-pits in the Lower Chalk.

North of Woolgarston a road slants westwards up the Downs and passes two pits; in the lower of which a nodular rock on the horizon of the Melbourn Rock was worked, while in the upper may be seen:—

		Ft.	In.
	Chalk with flints.		
	Beds not seen...	8	0
	Nodular chalk	12	0
Chalk Rock	Line of green nodules	—	2--3
	Nodular chalk	2	0

Here the Chalk Rock yielded the following fossils:—*

Plocoscyphia
Ventriculites
Discoidea
Porosphæra
Holaster
Micraster breviporus, *Ag.*
Rhynchonella Cuvieri, *D'Orb*
Terebratula biplicata, *Sow.*

Terebratula carnea, *Sow.*
„ semiglobosa, *Sow.*
Terebratulina gracilis, *Schloth.*
„ striata, *Wahl.*
Inoceramus
Spondylus spinosus, *Sow.*
Ostrea
Ptychodus

On the opposite side of the Downs the uppermost beds of the Chalk have been burnt for lime, but are now worked for road-metal, the rock being everywhere hardened near the line of fault, as at Ballard Point. A similar pit is worked south of Bollington Farm.

Near Sandy Hill Farm we get a view of the Chalk Marl and of thick-bedded, rather nodular chalk with thin partings of marl, which forms the Middle Chalk; it contains *Inoceramus mytiloides* in abundance. The Melbourn Rock is visible in the top of an old pit a few yards to the east. A good section is afforded in the Railway Cutting at Corfe Castle, though the freshly exposed surface does not exhibit the characteristic aspect of the various rock-bands so clearly as the old quarries; the Chalk Rock crops out on the east side of the cutting, 74 yards north from the centre of the bridge at the Manse, the section being as below:—

Railway Cutting, Corfe Castle.

		Ft.	In.
	Chalk with flints.		
	Marl	0	3
	Nodular chalk with a layer of flint near the top...	9	0
	Marl	0	1
	Nodular chalk...	6	0
	Marl	0	2
Chalk Rock	Line of green nodules	0	6
	Nodular chalk...	1	6

---

* Collected by J. Rhodes and identified by Messrs. G. Sharman and E. T. Newton.

The Chalk Rock passes nearly under St. Edward the Martyr's Gate, and the conical hill on which the castle stands is formed of the lower beds of the Upper Chalk, the *Micraster*-zones of M. Barrois. To the north of the hill a quarry has been opened by the roadside for road-metal; the chalk dips at an angle of 75° northwards, and though hardened and traversed in all directions by threads of calcite, as is usual so near the fault, is not contorted, as shown by M. Barrois in his Figure 13. He records from it *Magas pumilus* (type), *Inoceramus Cripsii*, Mant., *Belemnitella mucronata*, Schloth., to which we may add *Echinocorys vulgaris*, Breyn, and *Terebratula biplicata*, Sow.

Eighty yards south of West Mills, to the west of the Castle, a trial-hole gives a good view of the thick bed of marl in the Lower Chalk. It is interbedded with chalk in the upper part, and is overlain by six feet of nodular chalk (Melbourn Rock); the strata dip north at 72°. The marl has yielded*:—

Plant-remains.
Ossicles of star-fish.
Rhynchonella Cuvieri, *D'Orb.*
„ plicatilis, *Sow.*
Terebratula semiglobosa, *Sow.*
Terebratulina striata, *Wahl.*
Inoceramus Brongniarti, *Sow.*
Inoceramus mytiloides, *Mant.*
Ostrea vesicularis, *Lam.*
Pecten orbicularis, *Sow.*
Plicatula, fragment.
Enchodus.
Fish-remains.

Seven hundred yards westward we get a similar section in an old quarry, and in some larger pits north-east of Knowle Church we see massive chalk in bands of one to three feet thickness, with occasional small grey cylindrical flints and with nodular bands, resting upon 30 feet of nodular chalk. The whole belongs to the Middle Chalk, and shows the increasingly nodular character and the incoming of flints in this sub-division in a westward direction. The marl has been extensively quarried and mined for cement-making in the west end of Knowle Hill, close by the high road. At the top of the hill we recognise the hard cream-coloured nodular Chalk Rock, as identified by Mr. Whitaker,† and below it nodular chalk with a very few flints (Middle Chalk) In the great gash made by the excavation of the marl we can make out:—

		FT.	IN.
Middle Chalk and Melbourn Rock	Hard nodular chalk, top not seen ...	20	0
	Shaly nodular chalk	6	0
Lower Chalk (zone of *Belemnitella plena*)	Chalk and marl interbedded	3	0
	Marl...	12	0

Below this in the same neighbourhood we get alternations of chalk and marl which compose the Lower Chalk, while in the side of the high road the Chloritic Marl is exposed to view. On the northern side of the hill vertical and hardened Upper Chalk (belonging, according to M. Barrois, to the *Marsupites*-zone) is worked for road-metal and lime-burning. The pits described above have yielded the following fossils* :—

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* Collected by J. Rhodes and identified by Messrs. Sharman and Newton.

† "On the Chalk of the Southern Part of Dorset and Devon," *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 94 (1871).

Upper Chalk.

Sponge.
Cyphosoma.
Holaster.
Rhynchonella limbata, *Schloth.*
Terebratula semiglobosa, *Sow.*
Spondylus spinosus, *Sow.*

Middle Chalk and Melbourn Rock.

Sponge-markings.
Cidaris spine.
Rhynchonella Cuvieri, *D'Orb.*
Terebratulina gracilis, *Schoth.*
Inoceramus mytiloides, *Mant.*

Marl-bed in the upper part of the Lower Chalk.

Ossicles of starfish.
Inoceramus.
Ostrea.
Pecten orbicularis, *Sow.*
Ammonites.
Baculites.
Belemnitella plena, *Blainv.*
Scaphites æqualis, *Sow.*
Odontaspis.
Fish-remains.

The Downs for the next quarter of a mile include two parallel ridges, known as Stonehill Down and Ridgeway Hill, the valley between the two running along the strike and on the outcrop—as far as can be judged—of the *Marsupites*-zone, but whether the form of ground is due to an unusually soft bed or to a line of fault we are unable to say. At the west end of Stonehill Down chalk with shattered grey flints and with pockets of ferruginous clay is worked for lime-burning near the great fault.

There are several pits by the side of the road leading westwards up the Downs. The uppermost shows six feet of angular flint-gravel; the second exposes flinty chalk resting on 15 feet of nodular chalk, but does not quite reach the Chalk Rock; the third shows the base of the Middle Chalk and the marl-bed in the top of the Lower Chalk. On the road over the Downs north of Tyneham the Chalk Rock and the nodular chalk above it are quarried, and the marl-bed runs through an old pit 200 yards further east. On the top of the hill angular flint-gravel is dug to a depth of 3 feet, and along the northern slope, close up to the great fault, there is a series of pits in chalk with great flint-masses ranging up to 2 feet across.

Worbarrow Bay.

At Flower's Barrow we reach the coast again, and get a continuous section of the Lower, Middle and about half of the Upper Chalk. The top of the hill consists of chalk-with-flints deeply eaten into by angular flint-gravel, but about 40 yards below the trenches on the southern slope the Chalk Rock crops out in a somewhat inaccessible position, the section running as follows:—

---

* Collected by J. Rhodes and identified by Messrs. Sharman and Newton.

Flower's Barrow, Worbarrow Bay.

		Ft.	In.
Upper Chalk.	Chalk with flints.		
	Nodular chalk without flints, about	15	0
	Chalk Rock; a line of green nodules	0	3
Middle Chalk and Melbourn Rock 113 feet.	Chalk, generally nodular, but details not procurable	113	0
Lower Chalk, 117 ft. 6 in.	Chalk, details not procurable, about	20	0
	Marl	12	0
	Chalk and marl alternating; 12 feet from the base some grey flinty lumps with a core of black flint; the lower part full of glauconite	81	0
	Hard grey glauconitic rock with scattered phosphatic nodules and a large Ammonite (Chloritic Marl)	4	4

Upper Greensand. (*See* p. 151).

The following fossils have been collected in Worbarrow Bay and identified by Messrs. G. Sharman and E. T. Newton:—

Middle Chalk.

Porosphera urceolata, *Phil.*
Discoidea Dixoni, *Forbes.*
„ subuculus ?, *Klein.*
Cidaris, plate of.
Rhynchonella Cuvieri, *D'Orb.*
Terebratula semiglobosa, *Sow.*
Inoceramus mytiloides, *Mant.*

Lower Chalk.

Holaster trecensis, *Leym.*
Inoceramus ? Lamarkii, *D'Orb.* (near base).
Inoceramus, concentric ribs near together (near base).
Lima, fragment.
Ostrea vesicularis, *Lam.*
Pecten Beaveri, *Sow.* (zone of Belemnitella plena).
Spondylus.
Pleurotomaria perspectiva, *Mant.*
Ammonites Mantelli, *Sow.* (near base).
Ammonites rhotomagensis, *Brong.* (near base).
Scaphites æqualis, *Sow.*

It will be noticed that flints here make their appearance in the Lower Chalk for the first time, while the Middle Chalk has become so generally nodular that it is difficult to distinguish the Melbourn Rock. On the other hand, the marl-bed is readily recognised, both at the top of the cliff and on the beach in Cow Corner, where also the Chloritic Marl is generally visible. Westwards from Cow Corner the cliff nearly follows the strike, and is formed of the Upper Chalk, with the Chalk Rock gradually sloping down to the sea-level; it is inaccessible, except by boat—as is commonly the case with cliffs of Upper Chalk. The upper beds, however, can be examined in the bay known as Arish Mell: the chalk there dips about N.N.W., at 70° to 75°, and is traversed by planes of slickenside, many of which are parallel to the great fault, while others meander in all directions, often at angles of not more than 20° from the horizontal. On the west side of the bay M. Barrois identified the *Marsupites*-zone in some soft white chalk with small flints and about 170 feet thick; and to the east of the bay he found *Micraster coranguinum* abundantly in chalk with more numerous flints, both nodular and tabular. The following fossils have been collected by J. Rhodes from the cliffs in Arish Mell, and identified by Messrs. G. Sharman and E. T. Newton:—

Porosphæra Woodwardi, *Phil.*
„ globularis, *Phil.*
Bourgueticrinus.
Cidaris.
Serpula plexus, *Sow.*
Vermicularia.
Eschara or Flustra.
Flustra inelegans, *Lons.*
Entalophora pustulosa, *D'Orb.*
Laterolubigera.
Vincularia.
Rhynchonella plicatilis, *Sow.*
Terebratulina gracilis, *Schloth.*

Mupe Bay.

In Mupe Bay, and west of it, the outcrops of the sub-divisions of the Chalk are crowded into a very narrow belt owing to the steepness of the dip, which ranges from 70° to 90°. The beach is accessible on foot as far east as the Black Rock, near which is a little cave alluded to by M. Barrois as lying in the zone of *Micraster cortestudinarium*. One hundred yards further west a ridge of rock, composed of hard nodular chalk with lines of green nodules (the Chalk Rock), juts out from the cliff into the shingle-beach, as mentioned by Mr. Whitaker.* At this point we commence the following section:—

Section of the Chalk in Mupe Bay.

			Ft.	In.
Upper Chalk.		Chalk with flints.		
		Nodular chalk without flints, a massive rock...	15	0
		Parting	0	1
		Chalk	1	0
	Chalk Rock.	Line of green nodules	0	3
		Chalk	1	0
		Line of green nodules	0	3
Middle Chalk. 90 feet.		Chalk	3	0
		Chalk with lines of nodules, and occasional flints in the lower part...	36	0
		Ditto, more thickly bedded, an occasional flint at the base...	51	0
Lower Chalk 104 feet.	Belemnitella Zone.	Smooth chalk, with partings of marl	4	0
		Smooth chalky marl, passing down into ...	3	0
		Marl...	9	0
		Chalk with a line of flints 20 feet from top ...	30	0
		Ditto, with a few scattered flints about the middle	46	0
		Sandy chalk with siliceous nodules, some flint-hearted	12	0
	Chloritic Marl, apparently faulted out. (*See* p. 152).			

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* *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 95 (1871).

The following fossils have been collected in Mupe Bay by J. Rhodes, and identified by Messrs. G. Sharman and E. T. Newton:—

Upper Chalk (Zone of Holaster planus.)

Cyphosoma radiatum, *Sorrig.*
Cidaris, spine.
Echinoconus subrotundus, *Mant.*
Holaster planus, *Mant.*
Micraster breviporus, *Ag.*
Rhynchonella Cuvieri, *D'Orb.*
Terebratula carnea, *Sow.*
„ semiglobosa, *Sow.*
Inoceramus Brongniarti, *Sow.*
Spondylus spinosus, *Sow.*

Middle Chalk.

Entalophora.
Discoidea Dixoni, *Forbes.*
Rhynchonella Cuvieri, *D'Orb.*
Terebratula semiglobosa, *Sow.*
Terebratulina gracilis, *Schloth.*
Inoceramus mytiloides, *Mant.*
Lima spinosa, *Sow.*
Ostrea vesicularis, *Lam.*

Lower Chalk.

Holaster, fragment.
Inoceramus, concentric striæ near together (zone of Belemnitella plena).
Ammonites rhotomagensis, *Brong.*

Lulworth and Durdle.

The section at Lulworth is not so easily accessible as that in Mupe Bay, but the marl-bed can be reached without difficulty on the north-west side of the Cove. Flints occur in the Lower and Middle Chalk as well as in the lower beds of the Upper Chalk just above the Chalk Rock. The Middle Chalk shews markedly the nodular character which we have seen increasing westwards in every successive section. From the marl-bed *Belemnitella plena*, De Bl., *Ammonites* and *Hamites* are recorded by M. Barrois, and *Ammonites rhotomagensis*, Defr., from the Chalk Marl below. At its base the Chalk Marl contains nodules, grains of glauconite, and sand, and passes down into the Chloritic Marl, which is 3 feet 6 inches thick. The following fossils have been collected in Lulworth Cove by J. Rhodes and identified by Messrs. G. Sharman and E. T. Newton, except where otherwise noted:—

Middle Chalk.

Discoidea Dixoni, *Ag.*
„ subuculus, *Klein.*
Rhynchonella Cuvieri, *D'Orb.*
Terebratula biplicata, *Sow.*
Terebratula semiglobosa, *Sow.*
Inoceramus Brongniarti ?, *Sow.*
„ mytiloides, *Mant.*
Ammonites peramplus (?), *Mant.*

Chloritic Marl.

*Holaster subglobosus, *Ag.*
*Terebratula arcuata, *Röm.*
„ semiglobosa (?), *Sow.* or biplicata (?), *Sow.*
Arca, cast.
Cyprina (?), cast.
Avellana cassis, *D'Orb.*
*Ammonites Mantelli, *Sow.*
„ rhotomagensis, *Brong.*
„ varians, *Sow.*
* „ vectensis, *Sharpe.*
*Baculites.
Scaphites æqualis, *Sow.*
Turrilites Bergeri, *Brong.* fragment.

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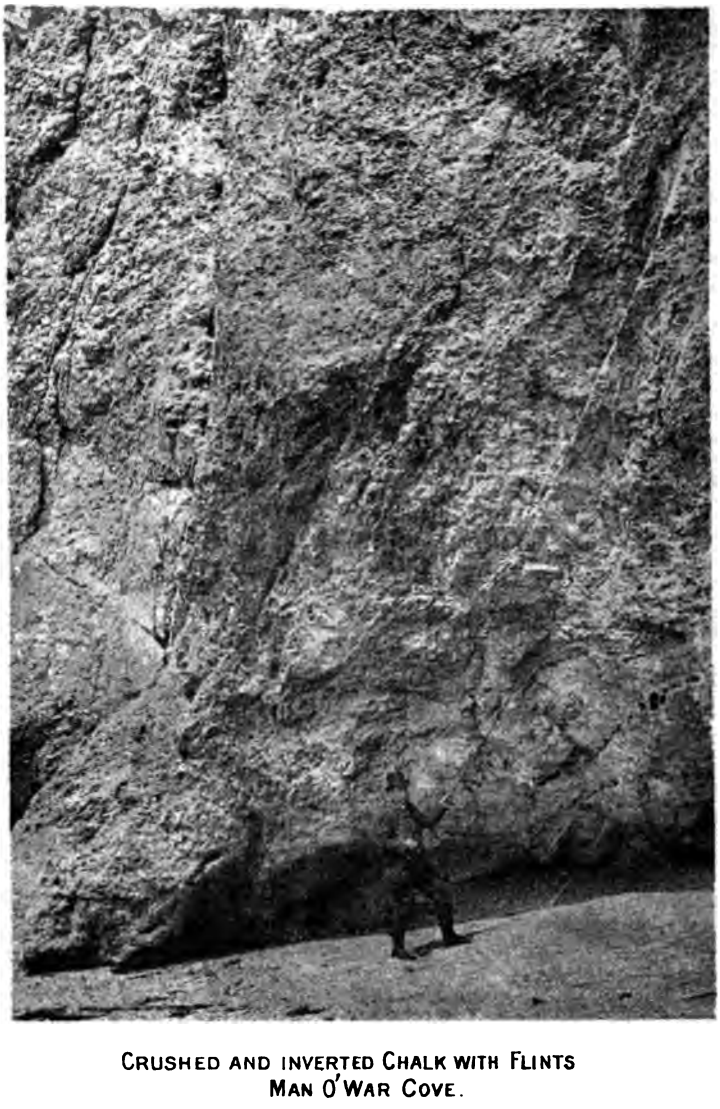
* Added to the list on the authority of M. Barrois, "Terrain Crétacé Supérieur," 1876. p. 93,



CRUSHED AND INVERTED CHALK WITH FLINTS
MAN O'WAR COVE.

The chalk-cliff which extends from near Dungy Head to Man-o'-War Cove gives full opportunity of studying the effects of the Isle of Purbeck Fault on the rock in its immediate neighbourhood. The fault runs at a distance of 350 yards from the base of the Chalk near Dungy Head, and 150 yards from the base at Man-o'-War Cove. All the chalk seen is inverted, so as to dip apparently southwards at angles of 60° to 70°, and is so crushed and squeezed that no reliance can be placed on its apparent thickness, though the principal divisions can be recognised. The marl-bed descends to the beach 50 yards beyond the top of the Upper Greensand; a few yards further on, and near where the Chalk Rock should occur, a belt of crushed chalk runs along the foot of the cliff; it is well exposed in the promontory opposite the Man-o'-War Rock, and there consists of a sharply defined vertical fissure varying from 1 to 6 feet in width and filled with crushed rock, some of the flints even being reduced to a black powder, and drawn out into black streaks like so much coal-dust (Plate V). At the bend of the promontory, the marl-bed crops out at high-water mark, and the top of the Upper Greensand at low-water mark, while the Portland Stone forms the Man-o'-War, the whole series of outcrops from Chalk Rock to Portland Stone being crowded into a belt about 90 yards broad. Allowing for the fact that the beds are not vertical, but slightly inverted, we may estimate their apparent thickness to be about 250 feet. But the true thickness of the group of strata of which representatives can be recognised in this narrow belt must exceed 1,000 feet. We are forced to conclude therefore that the Middle and Lower Chalk, the Upper Greensand and Gault, and the Wealden and Purbeck Beds have suffered compression to one-fourth of their original thickness.

Though all the formations are represented in this narrow space, there are undoubtedly portions of each missing. For example, knowledge of the true sequence of Purbeck Beds gained in the neighbourhood enables us to say that the Upper Purbeck strata are squeezed out in the promontory of Durdle Door, and again that a part of the Lower Purbeck division is squeezed out at Dungy Head, and that the Chalk Rock, Marl-bed, and Chloritic Marl are closer together than they should be. In many other cases, where the sequence of strata is less familiar, there are, no doubt, parts of the series unrepresented. The compression therefore seems to have caused the parts of the mass to slide over one another along a number of different bedding-planes, rather than along one definite line of fracture, and the fact that the whole series consists of alternations of sands and clays has probably facilitated the movement. It will be noticed that the compression is greater in the promontory above described than in the headland of Durdle Door, which lies next to it on the west.

In Man-o'-War Cove the line of crush in the chalk which follows the foot of the cliff in the bay last described once more comes out on the beach for about 60 yards, the flinty chalk on its north side having an apparent dip southwards of 60°, which of course is due to its being inverted 30° beyond the vertical.

Here also planes of slickenside traverse the rock so as to appear in the cliff-section to be nearly horizontal, though in reality they slope down southwards at angles of 20° or 30° from the horizontal. In many of these slide-planes it is possible to identify the rock-bands above and below, and so to determine the amount of the slide. In all cases the rock above the slide-plane has been pushed northwards over the rock below the plane, for a distance generally of 7 or 8 feet.

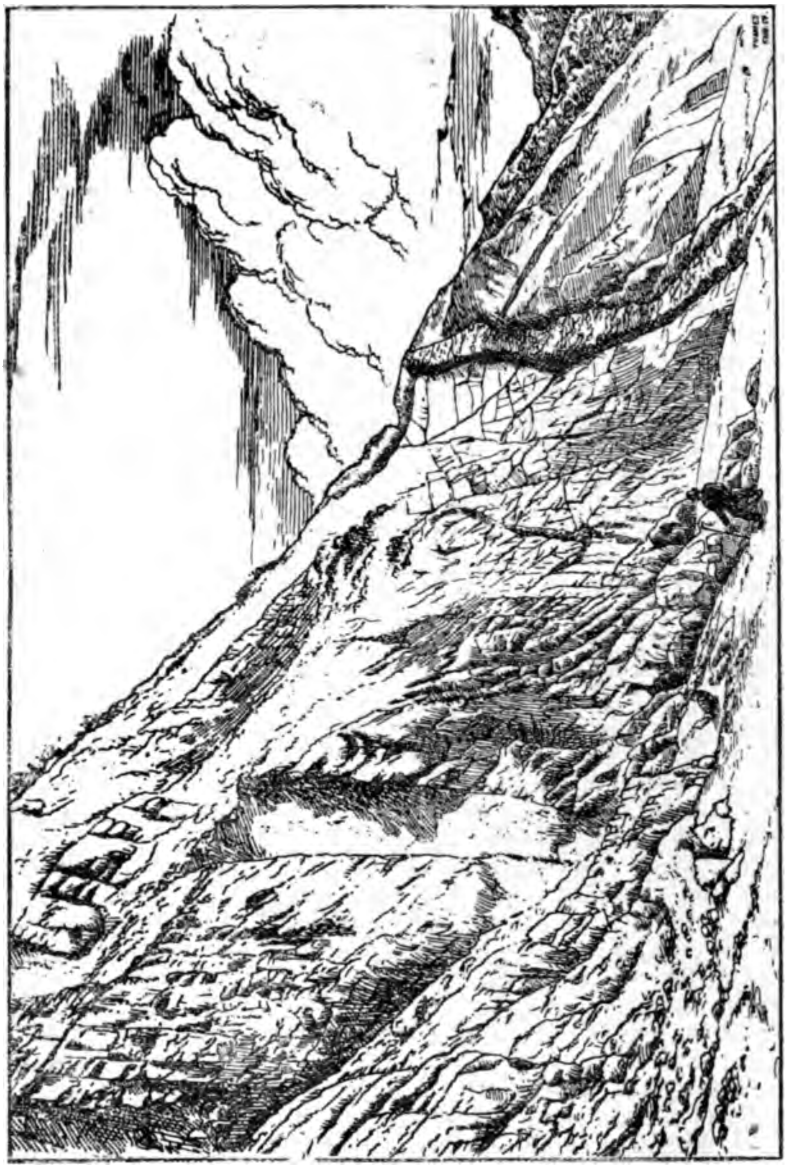


FIG. 178. Vertical Middle and Lower Chalk traversed by two nearly horizontal thrust-faults at Durdle Cove (looking east). *Drawn by H. W. G. Williams from a photograph.*

The illustration forming Fig. 178 shows the Marl-bed twice shifted by faults of this character. To the right are seen vertical Gault and Upper Greensand, a hard bed at the top of the latter forming a bold rib. Next to this comes much fractured Lower Chalk followed by the marl-bed. The seated figure marks the outcrop of the marl-bed at the foot of the cliff. A slide-plane running a few feet above the beach shifts it to the left, and another running near the top of the cliff shifts it again in the same direction.

The broken condition of the Chalk on the east side of Man-o'-War Cove prevents our recognising the Chalk Rock, but it can be seen on the west side of the cove up to a height of 5 feet above the beach, as noted by Mr. Whitaker, where it is cut off by a slide-plane. The marl-bed is 8 feet thick, and the nodular chalk immediately above it contains flints; the Chalk Marl has at its base the usual gritty band with grains of glauconite, quartz, and small brown nodules. On the western side of the promontory of Durdle Door both Chalk Rock and Marl-bed can be recognised, the former, however, almost coinciding with a line of crush, which is probably the same as that noted in the bays last described. Here, as in Man-o'-War Cove, the Middle and Lower Chalk are compressed to far less than their normal thickness, but the Upper Greensand is well represented, as already noted.

The Upper Chalk cliff of this bay gives an excellent opportunity of studying one of the slide-planes alluded to above. The plane is intersected by the cliff at 8 or 10 feet above high-water mark, and has given rise to a row of small caves (Fig. 179). On entering one of these we stand upon a slickensided floor of chalk, sloping down southwards at an angle of about 20°, while the cave itself has been hollowed out in hard flinty chalk in the usual inverted position, *i.e.*, with an apparent dip southwards of 70° to 80°. The slide-plane is at times a clean sharp cut, but more often contains 3 or 4 inches of ground-up chalk and flint hardened into a rock. In this case, as in the others, the roof has been pushed northwards over the floor. The fracture can be followed to a recess in the shore 250 yards west of Durdle Door, and there can be seen rising northwards until it loses itself in a mass of weathered rock in the upper part of the cliff.

West of this recess there is no more inversion, but perfectly vertical chalk-with-flints forms an inaccessible cliff for about three quarters of a mile, when the Isle of Purbeck fault runs out to sea. The section presented would probably resemble that at Ballard Point if the cliff intersected the fault at right angles or nearly so. It crosses it, however, so obliquely that it is difficult to distinguish the actual line of fracture in the mass of crushed chalk. In walking along the beach from Bat's Corner (accessible only by boat) we pass vertical chalk for 550 yards, and then for about 50 yards see only a belt of shattered rock, with planes of slickenside shooting through the mass in every direction, but principally east and west with a hade to the north; beyond this belt the chalk dips at first at an angle of 35°, but about 150 yards further on becomes horizontal. These distances are measured along a line oblique to the fault as before mentioned; they indicate that the strata become horizontal about 50 yards north of the fault, as at Ballard Point.

A few yards further westwards the strata dip to the south-east and east-south-east at angles varying from 10° to 30°, so that we proceed over lower beds and eventually reach the Chalk Rock at about two-thirds of a mile beyond the fault. For the [illegible] yards the chalk is faulted, though far less so than on [illegible] side of the fault; most of the faults run northwards [illegible] down eastwards at 10° to 30°.

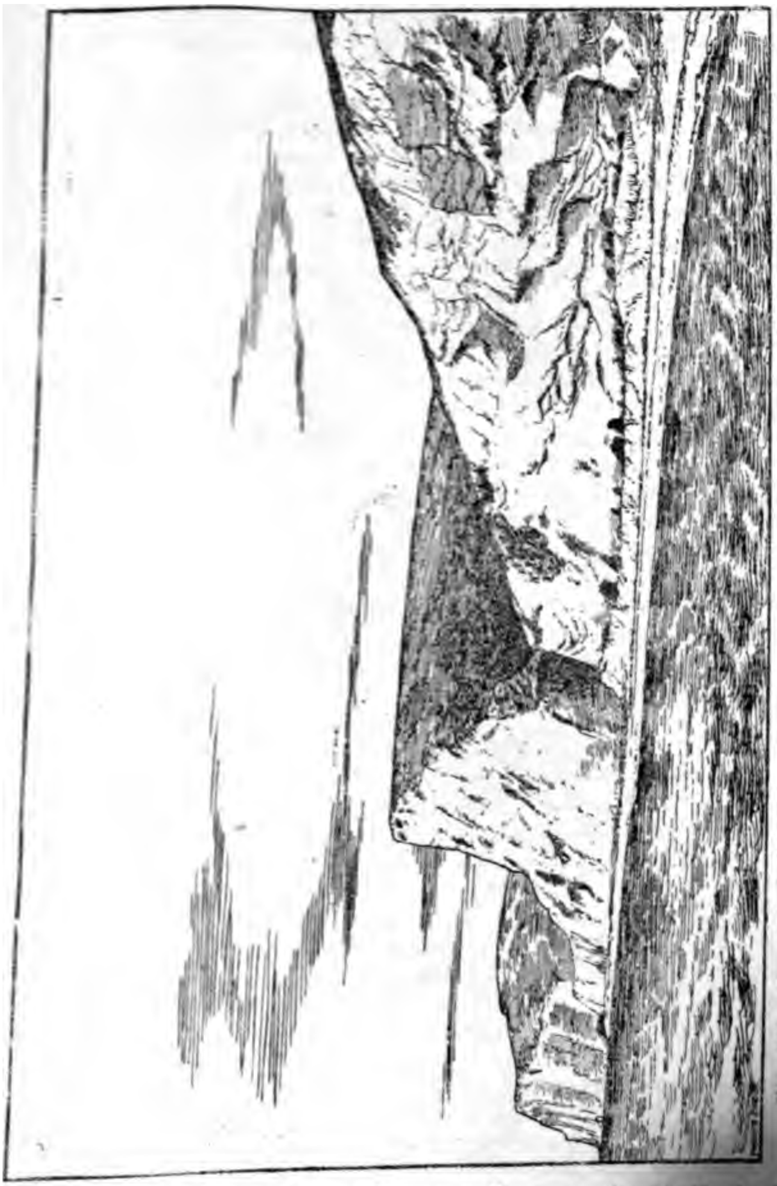


Fig. 179. Inverted chalk traversed by a nearly horizontal thrust-fault at Durdle Cove (looking west). *Drawn by H. W. G. Williams from a photograph.*

Here we leave the coast for the present to examine the chalk-area which extends to the margin of the Tertiary Basin near Coombe Keynes.

Coombe Keynes, Wool, and Winfrith. (Plate VII.)

As might have been expected from the occurrence of several Tertiary outliers, much of the chalk of this area belongs to the upper part of the Upper Chalk, namely the zone of *Belemnitella*. A small syncline runs parallel with and close to the great fault, and introduces irregular patches of Tertiary beds near East and West Lulworth. North of this syncline the beds rise at gentle angles and at the same time form the highest ground, then again descend gently to the Tertiary area. On its west side the tract is broken into by the anticline and valley of Chaldon, in which Purbeck and Wealden Beds come up to the surface; and though we cannot trace this anticline further east than Winfrith, yet we may infer that it has caused the upheaval of this great shoulder of chalk which so conspicuously breaks the regularity of the southern margin of the Tertiary basin.

The chalk of the tract we are now engaged upon was described by M. Barrois under the title of the *Massif de Lulworth*. From various pits, which it is impossible to identify, he obtained *Serpula plexus*, Sow., *Echinocorys gibbus*, Lam., *Magas pumilus*, *Rhynchonella limbata*, Sow., *R. subplicata*, Mant., *Belemnitella mucronata*, Schloth.*

A pit in the fork of the road a quarter of a mile north of Coombe Keynes exposes smooth white chalk with few flints, lying immediately under Tertiary beds; it has yielded:—†

Porosphæra.
Echinoderms and star-fish, fragments.
Kingena lima, *Defr.*
Magas pumilus, *Sow.*
Rhynchonella lineolata, *Phil.*
Rhynchonella plicatilis, *Sow.*
Lima allied to L. Galliennei, *D'Orb.*
Ostrea vesicularis, *Lam.*
Belemnitella mucronata, *Schloth.* abundant.

The Burton Pit, half a mile west-south-west of W[illegible] yielded all the above and in addition *Cyphosoma*, *Serpul*[illegible] Sow., *Flustra inelegans*, Lonsd., and *Rhynchonell*[illegible] Schloth.

In Lulworth Park, near the North Lodge [illegible] 250 yards apart; the eastern pit is clos[illegible] boundary, and shows chalk with the great fli[illegible] moudras in the upper part. It contained th[illegible]

Porosphæra.
Bourgueticrinus.
Serpula ilium, *Sow.*
Crania ignabergensis, *Retz.*
Magas pumilus, *Sow.*
[illegible]

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* Terrain Cr[illegible]

† Collected b[illegible] [illegible]ton.

Rhynchonella limbata, Dav., and *Belemnitella mucronata*, Schloth., were also recorded by M. Barrois, but the *Belemnitella* was not among the specimens collected during the present survey.

The more western of the two pits shows chalk-with-flints dipping eastwards at 5°, and therefore about 66 feet lower in the formation than the rock seen in the other pit. It contained *Porosphaera globularis*, Phil., *Serpula plexus*, Sow., *S. ilium*, Sow, *Vermicularia*, *Flustra inelegans*, Lons., *Crania ignabergensis*, Retz., *Magas pumilus*, Sow., *Rhynchonella plicatilis*, Sow., *Lima*, *Ostrea vesicularis*, Lam., *Pecten nitidus*, Mant., *P. quinquecostatus*, Sow., and Fish-scales.* Nearly half a mile south-south-west of Lulworth Castle there is a chalk-pit close to the Tertiary boundary, where the following were collected*:—

Porosphæra globularis, *Phil.*
Ventriculites.
Parasmilia centralis, *Mant.*
Serpula ilium, *Sow.*
„ plexus, *Sow.*
Pollicipes.
Entalophora.
Idmonea cretacea, *Eth. and Carp.*
Laterotubigera cenomana, *D'Orb.*
Multinodelea tuberosa, *D'Orb.*
Ditrupa deformis, *Lamk.*
Magas pumilus, *Sow.*
Rhynchonella plicatilis, *Sow.*
Terebratula semiglobosa, *Sow.*
Terebratulina.
Lima.
Ostrea vesicularis, *Lam.*
Pecten.
Spondylus.
Dentalium.
Fish-scales.

Next below the flinty chalk exposed in the pits mentioned above there occurs a soft, white, almost flintless chalk, which has been dug in some pits about half a mile south of Coombe Keynes.

White Nothe and Ringstead.

The Chalk Rock, at the outcrop of which we left the description of the coast-section, rises from the beach 740 yards east of the ledge formed by the chert-beds, and about 250 yards west of the depression known as West Bottom. The dip is steady at angles of 5° to 8°, and the band reaches the top of the cliff 600 yards west of the Coastguard Station. It presents the following details:—

		FT.	IN.
Upper Chalk	Layer of flint		
	Nodular chalk	7	0
	Parting of marl	0	1
	Nodular chalk with flints	2	0
	Nodular chalk without flints	5	0
	Smooth chalk with few flints	3	0
	Nodular chalk ; a band of yellowish and greenish nodules, in the topmost 18 inches (? Chalk Rock), *Spondylus spinosus*, *Rhynchonella*, *Terebratula carnea*, *T. semiglobosa*	6	0
Middle Chalk	Parting	0	0½
	Chalk with wavy and interlacing lines of dark marl	1	0
	Parting of dark wavy marl	0	1
	Chalk, as above	2	6
	Parting	0	0½
	Chalk with wavy lines of dark marl	20	0

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* Collected by J. Rhodes and identified by Messrs. Sharman and Newton.

Another detailed section was furnished by a fallen mass on the beach:—

		Ft.	In.
Upper Chalk	Chalk with flints; a tabular mass of flint, 2 to 6 inches thick, at bottom		
	Nodular chalk with a few scattered flints ...	15	0
	Two layers of green-coated nodules, separated by nodular chalk (Chalk Rock)	1	6
Middle Chalk	Nodular chalk	2	6
	Smooth, white chalk with an occasional flint ...	6	0
	Chalk with wavy laminæ of dark marl	6	0

The marl-bed rises from the beach 300 yards east of the ledge of the Chert Beds, and reaches the top of the cliff 280 yards west of White Nothe (Holworth) House. The cliff above the Chert Beds shows Lower Chalk consisting of alternations of smooth chalk and chalk-marl in thin regular beds, with layers of flints at 6 feet, 12 feet, and 30 feet above the base. Below it are three feet of very chalky Chloritic Marl. From this point M. Barrois ascended the cliff by a route now in part inaccessible, and recorded the following succession:—

	Ft.	In.
The *Marsupites*-zone is seen under the Signal Station and in a quarry a short distance to the north. Greyish flints in thin discontinuous bands.		
The *Micraster coranguinum*-zone forms the crest of the hill. Flints, pale-grey, superficially pink; at its base a conspicuous hard yellow nodular bed with many rolled fossils, about 1½ feet thick	116	0

Porosphæra globularis, *Phil.*
Serpula plexus, *Sow.*
Cidaris clavigera, *Kœnig.*
„ hirudo, *Sorig.*
„ peromata, *Forb.*
„ sceptrifera *Mant.*
„ subvesiculosa, *D'Orb.*
Cyphosoma sp.
Bourgueticrinus ellipticus, *Mall.*
Echinoconus conicus, *Breyn.*
Echinocorys gibbus, *Lk.*
Micraster coranguinum, *Forb.*
Inoceramus involutus, *Sow.*

	Ft.	In.
The *Micraster cortestudinarium*-zone contains cavernous, sometimes reddish, flints in the upper beds, but solid black flints in the lower part; several nodular bands	142	0

Porosphæra globularis, *Phil.*
Cidaris clavigera, *Kœnig.*
„ hirudo, *Sorig.*
„ sceptrifera, *Mant.*
„ subvesiculosa, *D'Orb.*
Discoidea.
Echinocorys gibbus, *Lk.*
Holaster planus, *Mant.*
Micraster corbovis (?), *Forbes.*
Parasmilia.
Salenia granulata, *Forbes.*
Rhynchonella plicatilis, *Sow.*
Terebratula semiglobosa, *Sow.*
Inoceramus.
Ostrea vesicularis, *Lk.*

	Ft.	In.
The *Holaster planus*-zone includes 1½ feet of hard nodular chalk [Chalk Rock] above, with 6½ feet of nearly flintless chalk below	8	0

Amorphospongia globosa, *v. Hag.*
Cyphosoma radiatum, *Sorig.*
Echinocorys gibbus, *Lk.*
Holaster planus, *Ag.* (*Mant.* sp.).
Micraster breviporus, *Ag.*
Micraster corbovis, *Forb.*
Terebratula semiglobosa, *Sow.*
Inoceramus, allied to labiatus.
Spondylus spinosus, *Sow.*

	Ft.	In
The *Terebratulina gracilis*-zone has black flints in the upper part and a few grey flints in the lower; at its top a thin seam of dark clay	82	0

Holaster coravium, *Lamk.*
Rhynchonella Cuvieri, *D'Orb.*
Inoceramus Brongniarti, *Sow.*
„ labiatus, *Schlt.*

The *Inoceramus labiatus*-zone is very nodular but flintless	65	5

Rhynchonella Cuvieri, *D'Orb.*
Inoceramus labiatus, *Schlt.*

The *Belemnites plenus* [*Belemnitella plena*]-zone is a greenish marl, very clayey in the lower 3 feet ...	9	10
The *Holaster subglobosus*-zone is a hard greyish marly chalk with beds of marl.—Many bluish-grey flints	32	7
The Chloritic Marl is sandy nodular and yellowish-brown, with grains of quartz and glauconite and phosphatic nodules. At its base *Holaster subglobosus* is so abundant as to form a continuous floor ...	3	4

Sponges.
Serpula vermes, *Sow.*
*Discoidea.
Echinoconus castanea, *D'Orb.*
Holaster subglobosus, *Ag.*
„ trecensis, *Leym.*
Arca sp.
*Exogyra.
*Cucullæa.
Panopæa, sp.
Avellana cassis, *D'Orb.*
*Pterocera.
Pleurotomaria sp.
Ammonites Coupei, *Brg.*
* „ navicularis, *Mant.*
„ rhotomagensis, *Defr.*
„ varians, *Sow.*
*Nautilus lævigatus, *D'Orb.*
Scaphites æqualis, *Sow.*
*Turrilites Wiestii, *Sharpe.*

The thickness assigned by M. Barrois to the Middle Chalk agrees with that given in the coast-section, Plate IX., but his estimate of 32 feet 7 inches for the strata between the Marl Bed and Chloritic Marl seems considerably too small.

It is worth noting that there are three little reversed faults in the cliff west of the Coastguard Station. One runs E. 35° S. and hades to the north, but throws the beds down south about 4 feet; this is seen in the Upper Chalk 100 yards west of the Station. Two other little overthrusts can be detected in the Chalk Marl and Chert Beds further west. They were due, no doubt, to the Isle of Purbeck disturbance, which must run but a short distance south of White Nothe.

The sections in the chalk between Upton and Ringstead are poor, but the marl-bed, much crushed, can be distinguished in a small pit north of South Down Farm; both the Lower and Middle Chalk are smashed, reversed, and faulted in every direction. This condition is due to the Ringstead post-Cretaceous disturbance, which throws the strata into the form of a syncline with the usual sharp upturn to the south. It here reaches its maximum intensity, but its effects can be detected through Chaldon

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* Included in the list from specimens collected by J. Rhodes, and identified by Messrs. Sharman & Newton.

Down in the shallow syncline indicated by the southerly dips at Brimstone Bottom Barn and Chaldon, and the northerly dip at Chaldon Barn Buildings. Westward also on Spring Bottom Hill, the Chalk and Greensand lie in a syncline, so that the whole of the long promontory of these rocks, from Chaldon Down to Osmington, seems to owe its preservation to the existence of this structure.

Along the Ridgeway Fault and North of it.

On the north side of the Chaldon Anticline the Upper Cretaceous Rocks have much the same structure as at Ballard Point, that is they are tilted up at a high angle along the Ridgeway disturbance, but gradually assume a gentle northerly dip at a short distance from it. As elsewhere described, the Ridgeway disturbance dies away east of Chaldon, but retains sufficient energy to have lifted the Upper Cretaceous Rocks into a graceful arch with the characteristic steep plunge down to the north.

The Middle and Lower Chalk, as a result of the steep dip, form narrow outcrops close along the foot of the escarpment. Chalk Marl and the nodular almost flintless Middle Chalk are repeatedly exposed, but there is no continuous section. Somewhere in the neighbourhood of Chaldon the abundance of *Galerites castanea* in the Chloritic Marl was noted by Edward Forbes in his description of that fossil.* At Five Marys (Five Meers) on the north flank of the hill M. Barrois collected *Beryx* sp. and *Pecten cretosus*, Defr., from a much shattered chalk with many flints, which he attributed to the zone of *Marsupites*, while at Owre Moigne and near Winfrith a soft, nearly flintless, white chalk has been dug, which probably belongs to the zone of *Belemnitellæ.* In all the pits there are indications of faulting and over-thrusting, and the sequence of Upper Chalk zones is probably incomplete.

From Owre Moigne westwards by Broadmayne, Whitcombe, and West Stafford, the *Belemnitella*-zone is soft and almost flintless. At Conygor Hill, near Whitcombe, and at Warmwell, it yielded to M. Barrois *Micraster*, *Magas pumilus*, var. Sow., *Rhynchonella octoplicata*, Sow., *Lima dutempleana*, D'Orb., *L. Hoperi*, Defr., *Pecten cretosus*, Defr., *Rostellaria stenoptera*, Gold., and *Belemnitella mucronata*, Schl. The Tertiary sands and gravels rest directly upon it, and as a result of their porosity the chalk is decomposed to a depth of 6 to over 20 feet into a structureless rubble. At Lulworth flinty chalk under similar conditions has perished into a loose mass of flint (p. 193).

Along the south side of these downs the lower zones of the chalk are crowded together in a narrow outcrop along the Ridgeway faults, as at Chaldon. The Chalk Marl can be identified in the foot of the White Horse Hill, and the Middle Chalk gives out a copious spring from which Weymouth is supplied. The base of that sub-division runs through a large pit by the side of the road from Sutton Poyntz to Dorchester, the lower part of the nodular chalk therein exposed having been identified by Messrs. Jukes-Browne and Hill as Melbourn rock. The marl-bed presumably lies a few feet below the floor of the quarry, for it can be seen to run about 14 feet below the base of the nodular chalk in a pit north of Bincombe Church. Here the following section was noted by Messrs. Jukes-Browne and Hill:—

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* Memoirs of the Geol. Survey. British Organic Remains, Dec. iii., Pl. vii.,

North of Bincombe Church.

		Ft.	In.
	Hard rather nodular chalk	4	0
Lower Chalk	Hard smooth chalk in lenticular beds with marly partings	14	0
	Tough grey marl	5	3
	Hard white chalk	3	0
	Less hard but firm chalk in thick beds, containing siliceous nodules with flint-cores ...	9	0

The entrance to the Ridgeway Tunnel traverses Middle and Lower Chalk dipping north at 85° and faulted on the south against Oxford Clay, but westwards these sub-divisions do not come to the surface at all, Upper Chalk being thrown by the fault against the Oolitic strata. The upturn is abrupt, for the dip is only 14° 400 yards north of the fault; it becomes still more so two-thirds of a mile westwards, where chalk with much flint curves from an inclination of 45° to one of 15° in a distance of 15 yards. North of Friar Waddon flinty chalk dips at 12° to 15° southwards towards the fault, thus indicating a little syncline and exactly reproducing the structure of the Isle of Purbeck Fault at Lulworth (p. 183). Near Portisham the Ridgeway Fault begins to die away, and the lower zones of the Chalk reappear in proper succession.

The Chalk Rock assumes an unusual aspect in the neighbourhood of Winterborne Steepleton. The long Winterborne Valley runs nearly along an anticline by which the *M. coranguinum*-zone is brought to the surface at Winterborne St. Martin, the *M. cortestudinarium*-zone half a mile further up, and the Chalk Rock near Rew Farm. The best sections are to be found in Kit Hill Bottom, a valley leading south-west half way between Steepleton and St. Martin. A small pit about 800 yards up the valley shows:—

	Ft.	In.
Flinty chalk	5	0
Nodular chalk	4	0
Band of white flint	0	0¼
Nodular chalk	3	0
Line of green nodules, like Chalk Rock.		

A little lower down the valley, and a few feet below this section, there occur:—

	Ft.	In.
Hard chalk with glauconite	3	0
Layer of flint	0	½
Band of quartz-grit with many black grains in a chalk-paste		3 to 6
Flinty chalk.		

The Chalk Rock again assumes an abnormal aspect in a pit on the left of the road from North Down to Steepleton. It occurs within the region affected by the Winterborne disturbance, and the strata dip at 50° :—

	Ft.	In.
Chalk with flints ; *Micraster cortestudinarium.*		
Strata not seen	10	0
Soft glauconitic chalk with small rounded lumps, looking like pebbles, but perhaps concretionary ...	1	0
Very rough nodular rock, the nodules consisting of hard creamy limestone ; large grains of quartz and nests of quartz and glauconite, with numerous foraminifera preserved in chalcedony	3	0
Soft glauconitic chalk, becoming more sandy and glauconitic below	5	0
Fault.		

The strata are crossed obliquely by the fault, which has the effect of repeating the outcrop of the rough nodular rock, the two outcrops running at about 5 feet distance and being parallel for some yards as though there were two beds. In the nodular rock there occur *Terebratula carnea* and *Pecten* (*Neithea*) *quadricostatus* ?[*]

Little Bredy to Askerswell.

From Little Bredy to Long Bredy the approximate position of the Chalk Rock is indicated by a steep brow which bounds the Upper Chalk plateau, but the rock itself is nowhere exposed. In ascending the downs, however, by the road running north-eastwards past Long Bredy Church, we find a glauconitic chalk, with flinty chalk above it, and a nodular rock with a few black flints below it. This glauconitic band probably corresponds to the glauconitic zone of the Winterborne valley ; it occurs here about 120 or 130 feet above the Upper Greensand.

Dowerfield Farm stands on Upper Chalk which is thrown directly against the Kimmeridge Clay by the Litton Cheney Fault. Three hundred yards west-south-west of the Farm there is a small pit, showing a hard stony chalk with flints and with a pale-red nodular band, 6 inches thick. This tint is rarely seen in the chalk of the South of England.

Half a mile west of Litton Cheney a chalk-pit by the roadside gives the following section :—

Near Litton Cheney

		Ft.	In.
Lower Chalk.	Hard nodular chalk ; partly laminated, and with dark streaks enclosing white lenticles ; partly made of alternations of smooth streaky chalk with rough nodular bands. A few flints in the lower part	25	0
	Grey marl or shaly chalk	0	1 to 3
	Massive chalk	9	0
	Blue clay	0	1
	Sandy white chalk (base not seen) ...	1	0
	Strata not seen	3	0
	Chloritic Marl (top not seen)	2	6
Upper Greensand—	Hard calcareous grit, seen to	6	0

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[*] See also Barrois, Terrain Crétacé Supérieur, 1876, p. 88.

dicate that the strata become horizontal about 50 yards north of the fault, as at Ballard Point.

A few yards further westwards the strata dip to the south-east and east-south-east at angles varying from 10° to 30°, so that we proceed over lower beds and eventually reach the Chalk Rock at about two-thirds of a mile beyond the fault. For the first 800 yards the chalk is faulted, though far less so than on the south side of the fault; most of the faults run northwards with a slope down eastwards at 10° to 30°.

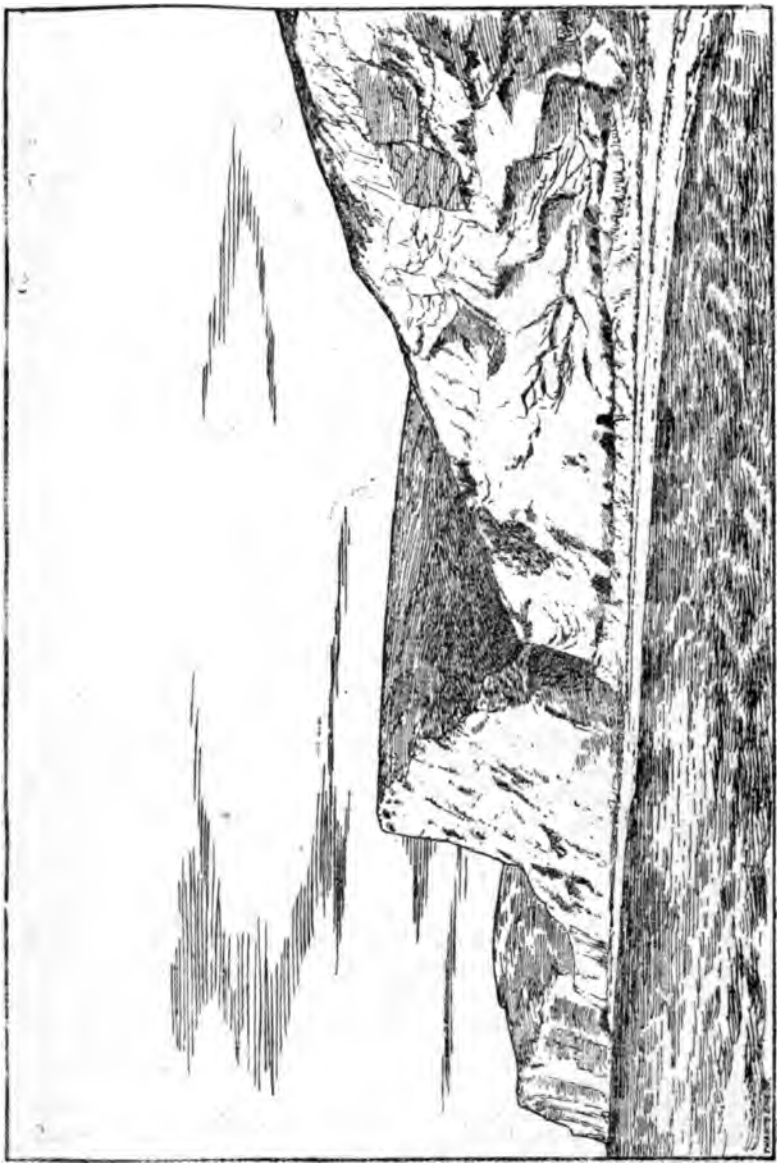

FIG. 179. Inverted chalk traversed by a nearly horizontal thrust-fault at Durdle Cove (looking west).
Drawn by H. W. G. Williams from a photograph.

Here we leave the coast for the present to examine the chalk-area which extends to the margin of the Tertiary Basin near Coombe Keynes.

Coombe Keynes, Wool, and Winfrith. (Plate VII.)

As might have been expected from the occurrence of several Tertiary outliers, much of the chalk of this area belongs to the upper part of the Upper Chalk, namely the zone of *Belemnitellæ*. A small syncline runs parallel with and close to the great fault, and introduces irregular patches of Tertiary beds near East and West Lulworth. North of this syncline the beds rise at gentle angles and at the same time form the highest ground, then again descend gently to the Tertiary area. On its west side the tract is broken into by the anticline and valley of Chaldon, in which Purbeck and Wealden Beds come up to the surface; and though we cannot trace this anticline further east than Winfrith, yet we may infer that it has caused the upheaval of this great shoulder of chalk which so conspicuously breaks the regularity of the southern margin of the Tertiary basin.

The chalk of the tract we are now engaged upon was described by M. Barrois under the title of the *Massif de Lulworth*. From various pits, which it is impossible to identify, he obtained *Serpula plexus*, Sow., *Echinocorys gibbus*, Lam., *Magas pumilus*, *Rhynchonella limbata*, Sow., *R. subplicata*, Mant., *Belemnitella mucronata*, Schloth.*

A pit in the fork of the road a quarter of a mile north of Coombe Keynes exposes smooth white chalk with few flints, lying immediately under Tertiary beds; it has yielded:—†

Porosphæra.
Echinoderms and star-fish, fragments.
Kingena lima, *Defr.*
Magas pumilus, *Sow.*
Rhynchonella lineolata, *Phil.*
Rhynchonella plicatilis, *Sow.*
Lima allied to L. Galliennei, *D'Orb.*
Ostrea vesicularis, *Lam.*
Belemnitella mucronata, *Schloth.*, abundant.

The Burton Pit, half a mile west-south-west of Wool, has yielded all the above and in addition *Cyphosoma*, *Serpula ilium*, Sow., *Flustra inelegans*, Lonsd., and *Rhynchonella limbata*, Schloth.

In Lulworth Park, near the North Lodge, there are two pits, 250 yards apart; the eastern pit is close to the Tertiary boundary, and shows chalk with the great flints known as paramoudras in the upper part. It contained the following fossils —†

Porosphæra.
Bourgueticrinus.
Serpula ilium, *Sow.*
Crania ignabergensis, *Retz.*
Magas pumilus, *Sow.*
Rhynchonella plicatilis, *Sow*
Ostrea normaniana, *D'Orb.*
,, vesicularis, *Lam.*
Pecten (Neithea) quinquecostatus, *Sow.*

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* "Terrain Crétacé Supérieur," pp. 98, 99.

† Collected by J. Rhodes and identified by Messrs. Sharman and E. T. Newton.

Rhynchonella limbata, Dav., and *Belemnitella mucronata*, Schloth., were also recorded by M. Barrois, but the *Belemnitella* was not among the specimens collected during the present survey.

The more western of the two pits shows chalk-with-flints dipping eastwards at 5°, and therefore about 66 feet lower in the formation than the rock seen in the other pit. It contained *Porosphæra globularis*, Phil., *Serpula plexus*, Sow., *S. ilium*, Sow, *Vermicularia*, *Flustra inelegans*, Lons., *Crania ignabergensis*, Retz., *Magas pumilus*, Sow., *Rhynchonella plicatilis*, Sow., *Lima*, *Ostrea vesicularis*, Lam., *Pecten nitidus*, Mant., *P. quinquecostatus*, Sow., and Fish-scales.* Nearly half a mile south-south-west of Lulworth Castle there is a chalk-pit close to the Tertiary boundary, where the following were collected*:—

Porosphæra globularis, *Phil.*
Ventriculites.
Parasmilia centralis, *Mant.*
Serpula ilium, *Sow.*
,, plexus, *Sow.*
Pollicipes.
Entalophora.
Idmonea cretacea, *Eth. and Carp.*
Laterotubigera cenomana, *D'Orb.*
Multinodelea tuberosa, *D'Orb.*
Ditrupa deformis, *Lamk.*
Magas pumilus, *Sow.*
Rhynchonella plicatilis, *Sow.*
Terebratula semiglobosa, *Sow.*
Terebratulina.
Lima.
Ostrea vesicularis, *Lam.*
Pecten.
Spondylus.
Dentalium.
Fish-scales.

Next below the flinty chalk exposed in the pits mentioned above there occurs a soft, white, almost flintless chalk, which has been dug in some pits about half a mile south of Coombe Keynes.

White Nothe and Ringstead.

The Chalk Rock, at the outcrop of which we left the description of the coast-section, rises from the beach 740 yards east of the ledge formed by the chert-beds, and about 250 yards west of the depression known as West Bottom. The dip is steady at angles of 5° to 8°, and the band reaches the top of the cliff 600 yards west of the Coastguard Station. It presents the following details:—

		FT.	IN.
Upper Chalk	Layer of flint		
	Nodular chalk	7	0
	Parting of marl	0	1
	Nodular chalk with flints	2	0
	Nodular chalk without flints	5	0
	Smooth chalk with few flints	3	0
	Nodular chalk; a band of yellowish and greenish nodules, in the topmost 18 inches (? Chalk Rock), *Spondylus spinosus*, *Rhynchonella*, *Terebratula carnea*, *T. semiglobosa*	6	0
Middle Chalk	Parting	0	0½
	Chalk with wavy and interlacing lines of dark marl	1	0
	Parting of dark wavy marl	0	1
	Chalk, as above	2	6
	Parting	0	0½
	Chalk with wavy lines of dark marl	20	0

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* Collected by J. Rhodes and identified by Messrs. Sharman and Newton.

Another detailed section was furnished by a fallen mass on the beach:—

		Ft.	In.
Upper Chalk	Chalk with flints; a tabular mass of flint, 2 to 6 inches thick, at bottom		
	Nodular chalk with a few scattered flints ...	15	0
	Two layers of green-coated nodules, separated by nodular chalk (Chalk Rock)	1	6
Middle Chalk	Nodular chalk	2	6
	Smooth, white chalk with an occasional flint ...	6	0
	Chalk with wavy laminæ of dark marl	6	0

The marl-bed rises from the beach 300 yards east of the ledge of the Chert Beds, and reaches the top of the cliff 280 yards west of White Nothe (Holworth) House. The cliff above the Chert Beds shows Lower Chalk consisting of alternations of smooth chalk and chalk-marl in thin regular beds, with layers of flints at 6 feet, 12 feet, and 30 feet above the base. Below it are three feet of very chalky Chloritic Marl. From this point M. Barrois ascended the cliff by a route now in part inaccessible, and recorded the following succession:—

Ft. In.

The *Marsupites*-zone is seen under the Signal Station and in a quarry a short distance to the north. Greyish flints in thin discontinuous bands.

The *Micraster coranguinum*-zone forms the crest of the hill. Flints, pale-grey, superficially pink; at its base a conspicuous hard yellow nodular bed with many rolled fossils, about 1½ feet thick 116 0

Porosphæra globularis, *Phil.*
Serpula plexus, *Sow.*
Cidaris clavigera, *Kœnig.*
„ hirudo, *Sorig.*
„ peromata, *Forb.*
„ sceptrifera *Mant.*
„ subvesiculosa, *D'Orb.*

Cyphosoma sp.
Bourgueticrinus ellipticus, *Mall.*
Echinoconus conicus, *Breyn.*
Echinocorys gibbus, *Lk.*
Micraster coranguinum, *Forb.*
Inoceramus involutus, *Sow.*

The *Micraster cortestudinarium*-zone contains cavernous, sometimes reddish, flints in the upper beds, but solid black flints in the lower part; several nodular bands 142 0

Porosphæra globularis, *Phil.*
Cidaris clavigera, *Kœnig.*
„ hirudo, *Sorig.*
„ sceptrifera, *Mant.*
„ subvesiculosa, *D'Orb.*
Discoidea.
Echinocorys gibbus, *Lk.*
Holaster planus, *Mant.*

Micraster corbovis (?), *Forbes.*
Parasmilia.
Salenia granulata, *Forbes.*
Rhynchonella plicatilis, *Sow.*
Terebratula semiglobosa, *Sow.*
Inoceramus.
Ostrea vesicularis, *Lk.*

The *Holaster planus*-zone includes 1½ feet of hard nodular chalk [Chalk Rock] above, with 6½ feet of nearly flintless chalk below 8 0

Amorphospongia globosa, *v. Hag.*
Cyphosoma radiatum, *Sorig.*
Echinocorys gibbus, *Lk.*
Holaster planus, *Ag.* (*Mant.* sp.).
Micraster breviporus, *Ag.*

Micraster corbovis, *Forb.*
Terebratula semiglobosa, *Sow.*
Inoceramus, allied to labiatus.
Spondylus spinosus, *Sow.*

Ft. In

The *Terebratulina gracilis*-zone has black flints in the upper part and a few grey flints in the lower; at its top a thin seam of dark clay 82 0

Holaster coravium, *Lamk.*
Rhynchonella Cuvieri, *D'Orb.*
Inoceramus Brongniarti, *Sow.*
„ labiatus, *Schlt.*

The *Inoceramus labiatus*-zone is very nodular but flintless 65 5

Rhynchonella Cuvieri, *D'Orb.*
Inoceramus labiatus, *Schlt.*

The *Belemnites plenus* [*Belemnitella plena*]-zone is a greenish marl, very clayey in the lower 3 feet ... 9 10

The *Holaster subglobosus*-zone is a hard greyish marly chalk with beds of marl.—Many bluish-grey flints 32 7

The Chloritic Marl is sandy nodular and yellowish-brown, with grains of quartz and glauconite and phosphatic nodules. At its base *Holaster subglobosus* is so abundant as to form a continuous floor ... 3 4

Sponges.
Serpula vermes, *Sow.*
*Discoidea.
Echinoconus castanea, *D'Orb.*
Holaster subglobosus, *Ag.*
„ trecensis, *Leym.*
Arca sp.
*Exogyra.
*Cucullæa.
Panopæa, sp.
Avellana cassis, *D'Orb.*
*Pterocera.
Pleurotomaria sp.
Ammonites Coupei, *Brg.*
* „ navicularis, *Mant.*
„ rhotomagensis, *Defr.*
„ varians, *Sow.*
*Nautilus lævigatus, *D'Orb.*
Scaphites æqualis, *Sow.*
*Turrilites Wiestii, *Sharpe.*

The thickness assigned by M. Barrois to the Middle Chalk agrees with that given in the coast-section, Plate IX., but his estimate of 32 feet 7 inches for the strata between the Marl Bed and Chloritic Marl seems considerably too small.

It is worth noting that there are three little reversed faults in the cliff west of the Coastguard Station. One runs E. 35° S. and hades to the north, but throws the beds down south about 4 feet; this is seen in the Upper Chalk 100 yards west of the Station. Two other little overthrusts can be detected in the Chalk Marl and Chert Beds further west. They were due, no doubt, to the Isle of Purbeck disturbance, which must run but a short distance south of White Nothe.

The sections in the chalk between Upton and Ringstead are poor, but the marl-bed, much crushed, can be distinguished in a small pit north of South Down Farm; both the Lower and Middle Chalk are smashed, reversed, and faulted in every direction. This condition is due to the Ringstead post-Cretaceous disturbance, which throws the strata into the form of a syncline with the usual sharp upturn to the south. It here reaches its maximum intensity, but its effects can be detected through Chaldon

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* Included in the list from specimens collected by J. Rhodes, and identified by Messrs. Sharman & Newton.

Down in the shallow syncline indicated by the southerly dips at Brimstone Bottom Barn and Chaldon, and the northerly dip at Chaldon Barn Buildings. Westward also on Spring Bottom Hill, the Chalk and Greensand lie in a syncline, so that the whole of the long promontory of these rocks, from Chaldon Down to Osmington, seems to owe its preservation to the existence of this structure.

Along the Ridgeway Fault and North of it.

On the north side of the Chaldon Anticline the Upper Cretaceous Rocks have much the same structure as at Ballard Point, that is they are tilted up at a high angle along the Ridgeway disturbance, but gradually assume a gentle northerly dip at a short distance from it. As elsewhere described, the Ridgeway disturbance dies away east of Chaldon, but retains sufficient energy to have lifted the Upper Cretaceous Rocks into a graceful arch with the characteristic steep plunge down to the north.

The Middle and Lower Chalk, as a result of the steep dip, form narrow outcrops close along the foot of the escarpment. Chalk Marl and the nodular almost flintless Middle Chalk are repeatedly exposed, but there is no continuous section. Somewhere in the neighbourhood of Chaldon the abundance of *Galerites castanea* in the Chloritic Marl was noted by Edward Forbes in his description of that fossil.* At Five Marys (Five Meers) on the north flank of the hill M. Barrois collected *Beryx* sp. and *Pecten cretosus*, Defr., from a much shattered chalk with many flints, which he attributed to the zone of *Marsupites*, while at Owre Moigne and near Winfrith a soft, nearly flintless, white chalk has been dug, which probably belongs to the zone of *Belemnitellæ*. In all the pits there are indications of faulting and over-thrusting, and the sequence of Upper Chalk zones is probably incomplete.

From Owre Moigne westwards by Broadmayne, Whitcombe, and West Stafford, the *Belemnitella*-zone is soft and almost flintless. At Conygor Hill, near Whitcombe, and at Warmwell, it yielded to M. Barrois *Micraster*, *Magas pumilus*, var. Sow., *Rhynchonella octoplicata*, Sow., *Lima dutempleana*, D'Orb., *L. Hoperi*, Defr., *Pecten cretosus*, Defr., *Rostellaria stenoptera*, Gold., and *Belemnitella mucronata*, Schl. The Tertiary sands and gravels rest directly upon it, and as a result of their porosity the chalk is decomposed to a depth of 6 to over 20 feet into a structureless rubble. At Lulworth flinty chalk under similar conditions has perished into a loose mass of flint (p. 193).

Along the south side of these downs the lower zones of the chalk are crowded together in a narrow outcrop along the Ridgeway faults, as at Chaldon. The Chalk Marl can be identified in the foot of the White Horse Hill, and the Middle Chalk gives out a copious spring from which Weymouth is supplied. The base of that sub-division runs through a large pit by the side of the road from Sutton Poyntz to Dorchester, the lower part of the nodular chalk therein exposed having been identified by Messrs. Jukes-Browne and Hill as Melbourn rock. The marl-bed presumably lies a few feet below the floor of the quarry, for it can be seen to run about 14 feet below the base of the nodular chalk in a pit north of Bincombe Church. Here the following section was noted by Messrs. Jukes-Browne and Hill:—

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* Memoirs of the Geol. Survey. British Organic Remains, Dec. iii., Pl. vii.,

North of Bincombe Church.

		Ft.	In.
	Hard rather nodular chalk	4	0
Lower Chalk	Hard smooth chalk in lenticular beds with marly partings	14	0
	Tough grey marl	5	3
	Hard white chalk	3	0
	Less hard but firm chalk in thick beds, containing siliceous nodules with flint-cores ...	9	0

The entrance to the Ridgeway Tunnel traverses Middle and Lower Chalk dipping north at 85° and faulted on the south against Oxford Clay, but westwards these sub-divisions do not come to the surface at all, Upper Chalk being thrown by the fault against the Oolitic strata. The upturn is abrupt, for the dip is only 14° 400 yards north of the fault; it becomes still more so two-thirds of a mile westwards, where chalk with much flint curves from an inclination of 45° to one of 15° in a distance of 15 yards. North of Friar Waddon flinty chalk dips at 12° to 15° southwards towards the fault, thus indicating a little syncline and exactly reproducing the structure of the Isle of Purbeck Fault at Lulworth (p. 183). Near Portisham the Ridgeway Fault begins to die away, and the lower zones of the Chalk reappear in proper succession.

The Chalk Rock assumes an unusual aspect in the neighbourhood of Winterborne Steepleton. The long Winterborne Valley runs nearly along an anticline by which the *M. coranguinum*-zone is brought to the surface at Winterborne St. Martin, the *M. cortestudinarium*-zone half a mile further up, and the Chalk Rock near Rew Farm. The best sections are to be found in Kit Hill Bottom, a valley leading south-west half way between Steepleton and St. Martin. A small pit about 800 yards up the valley shows:—

	Ft.	In.
Flinty chalk	5	0
Nodular chalk	4	0
Band of white flint	0	0¼
Nodular chalk	3	0
Line of green nodules, like Chalk Rock.		

A little lower down the valley, and a few feet below this section, there occur:—

	Ft.	In.
Hard chalk with glauconite	3	0
Layer of flint	0	½
Band of quartz-grit with many black grains in a chalk-paste		3 to 6
Flinty chalk.		

The Chalk Rock again assumes an abnormal aspect in a pit on the left of the road from North Down to Steepleton. It occurs within the region affected by the Winterborne disturbance, and the strata dip at 50°:—

	Ft.	In.
Chalk with flints ; *Micraster cortestudinarium.*		
Strata not seen	10	0
Soft glauconitic chalk with small rounded lumps, looking like pebbles, but perhaps concretionary ...	1	0
Very rough nodular rock, the nodules consisting of hard creamy limestone ; large grains of quartz and nests of quartz and glauconite, with numerous foraminifera preserved in chalcedony	3	0
Soft glauconitic chalk, becoming more sandy and glauconitic below	5	0
Fault.		

The strata are crossed obliquely by the fault, which has the effect of repeating the outcrop of the rough nodular rock, the two outcrops running at about 5 feet distance and being parallel for some yards as though there were two beds. In the nodular rock there occur *Terebratula carnea* and *Pecten* (*Neithea*) *quadricostatus*? *

Little Bredy to Askerswell.

From Little Bredy to Long Bredy the approximate position of the Chalk Rock is indicated by a steep brow which bounds the Upper Chalk plateau, but the rock itself is nowhere exposed. In ascending the downs, however, by the road running north-eastwards past Long Bredy Church, we find a glauconitic chalk, with flinty chalk above it, and a nodular rock with a few black flints below it. This glauconitic band probably corresponds to the glauconitic zone of the Winterborne valley; it occurs here about 120 or 130 feet above the Upper Greensand.

Dowerfield Farm stands on Upper Chalk which is thrown directly against the Kimmeridge Clay by the Litton Cheney Fault. Three hundred yards west-south-west of the Farm there is a small pit, showing a hard stony chalk with flints and with a pale-red nodular band, 6 inches thick. This tint is rarely seen in the chalk of the South of England.

Half a mile west of Litton Cheney a chalk-pit by the roadside gives the following section:—

Near Litton Cheney

		Ft.	In.
Lower Chalk.	Hard nodular chalk ; partly laminated, and with dark streaks enclosing white lenticles ; partly made of alternations of smooth streaky chalk with rough nodular bands. A few flints in the lower part	25	0
	Grey marl or shaly chalk	0	1 to 3
	Massive chalk	9	0
	Blue clay	0	1
	Sandy white chalk (base not seen) ...	1	0
	Strata not seen	3	0
	Chloritic Marl (top not seen)	2	6
Upper Greensand—	Hard calcareous grit, seen to	6	0

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* See also Barrois, Terrain Crétacé Supérieur, 1876, p. 88.

The Chloritic Marl contains rolled brown phosphatic casts of fossils in a matrix of chalky glauconitic marl. At its base the phosphates are especially abundant, and are mixed with vivid-green rolled fragments of grit and many dark-green or black grains. The surface of the cherty grit below is vivid-green, and has been eroded into holes, in which the marl rests. Reference has elsewhere been made to the slight break at the base of the Chloritic Marl suggested by this and other sections (p. 162).

There are no exposures of either Melbourn or Chalk Rock on Askerswell Down, but a hard nodular rock underlying the Camp on Chilcombe Hill corresponds in character to the Middle Chalk. The base must be about 40 feet above the top of the Upper Greensand, and below it, to the south of the Camp, Chalk Marl is exposed to the thickness of upwards of 20 feet. On the promontory of Chalk north of Askerswell Melbourn Rock has been identified by Mr. Jukes-Browne at a height of about 70 feet above the top of the Upper Greensand. To the north-west of the Camp the Chloritic Marl, with much glauconite and many rolled phosphatic casts at its base, is dug through in quarrying the uppermost grit of the Upper Greensand for road-metal; the top-surface of the grit is nodular and vivid-green, as at Litton Cheney.

CHAPTER XIII.—TERTIARY BEDS.

Introduction.

The full description of the Tertiary strata of the Hampshire basin is reserved for another memoir, but a few notes on the occurrences of those strata in the district treated of in this volume will not be out of place. The mapping of the Tertiary area was carried out by Mr. Reid, who furnishes a part of the following observations.

Three subdivisions of the Eocene group are represented, namely, the Lower Bagshot Beds, the London Clay, and the Woolwich and Reading Series. Though subject to constant local changes, there seems to be a general tendency in all three formations to become coarser, and either estuarine or fluviatile westwards. The Bagshot Beds especially become conspicuously gravelly, and have been found by Mr. Reid to cut through the London Clay so as to rest directly upon the Chalk. At the same time the Chalk itself seems to have been deeply denuded before and during the Eocene period, so much so that the Upper Greensand, Purbeck, and perhaps still older rocks were laid bare at no great distance westwards. The evidence points to the materials of the gravels of both the Reading and the Bagshot Beds having been brought from the west, and principally by fluviatile action.

Studland and Corfe.

The junction of the Reading Beds with the Chalk is finely shown on the south side of Studland Bay. The Chalk is so much piped that an undisturbed section is exceptional, but about 40 feet of white sand are seen sometimes with upwards of 6 feet of mottled clay, at others with a hard ferruginous grit with rolled flints at its base (p. 170). The London Clay forms an outcrop of 130 to 200 yards in width, which indicates a thickness of about 80 or 100 feet. The village and the heaths behind it stand upon variegated sands and clays belonging to the Bagshot Beds.

About two miles west of Studland the Isle of Purbeck Fault runs into the Tertiary base, and from that point for some miles westwards both the Reading Beds and the Chalk are highly tilted. The sequence of strata, however, seems generally to be complete, for the mottled clays and sands of the Reading Beds can be detected at intervals all along the fault except for a short distance near Corfe Castle. The London Clay also maintains its breadth of outcrop, as though it were not dipping steeply, except in that same neighbourhood.

In the neighbourhood of Corfe Castle white and red mottled clays in the Bagshot Series have been worked for some centuries. They used to be dug in open pits and yielded leaves of fan-palm and other sub-tropical genera, as well as insects, but no molluscs or other calcareous organisms. At present the clays are worked in mines and fossils are seldom seen. They are used for pottery and earthenware, but not for china. "The water which filtered through the spoil-banks of the clay-pits is highly charged with sulphates, and from the presence of potash, was formerly used for the manufacture of alum. The presence of iron, however, spoils it for that purpose."[*]

An analysis of the Clay from Branksea Island by Professor Way yielded the following percentages[†]:—

	White Clay.	Black Clay.
Silica	65·49	72·23
Alumina	21·28	23·25
Oxide of iron	1·26	2·54
Alkalies and alkaline earths	7·25	1·78
Sulphate of lime	4·72	0·00
	100·00	99·80

A clay-pit near Corfe yielded the following section according to Damon[‡]:—

	FT.
Beds of lignite, about	10
Grey clay with carbonised leaves of plants	2
Yellow sand with leaves	2
Ferruginous band, a few inches	–
White sand, about	30
Pipe clay, 11 to	14
	58

The Matcham Pits yielded the following section in 1882, according to Mr. W. H. Hudleston:—

	FT.
Black earth and surface-material, with flints—indications of sepulture, &c.	
1. Loose white sand with *Ironstone Bands* at base	20–40
2. Stiff yellowish or variegated clay—"pipe-clay"	30
3. Pure "Potter's Clay" with leaves, &c.	8
4. Lignite, or Brown Coal	2
Clay	

"No. 3 is the article so much sought after; it is a soft, white, and somewhat unctuous clay . . . In the Nordon workings the lignite (No. 4) was sometimes found to be 7 or 8 feet thick and was occasionally used as fuel by the workpeople." §

Lulworth. (Plate VII., Sections 2 and 3).

Near Lulworth the fault leaves the Tertiary base again, and both the London Clay and the Reading Beds overspread large areas in a nearly horizontal position. The former, however, consists principally of sand more or less ferruginous and sometimes coarse, while the Reading Beds contain coarse gravel with almost unworn flints. The line of fault is marked out with great exactness, for buff sand or bright-red and mottled clay repeatedly occur in close proximity to Chalk. Similar sand and brightly coloured clays form the base of the Reading Beds round the Chalk-inlier of Arish Mell, so that the sequence of strata seems to be complete along the fault at Lulworth, as it is through most of Purbeck. The best exposures are yielded by a sand-pit east of St. Andrew's Farm and a gravel-pit in a plantation one mile E.N.E. of the farm. There are several swallow-holes in the Reading Beds 700 yards S.S.E. of Lulworth Castle.

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[*] J. Trimmer, *Journ. Royal Agricult. Soc.*, vol. xvi., p. 131, 1855.

[†] *Ibid.*

[‡] Geology of Weymouth, 2nd Ed., 1884, p. 141.

§ *Proc. Geol. Assoc.*, vol. vii., p. 378 (1883).

The Reading Beds seem to have extended at a comparatively recent date along the hill-side north of Lulworth, for though the Chalk comes to the surface it is loaded with greywethers and great blocks of flint-breccia. Following the line of these blocks we are led to a long outlier on Newlands Warren of buff and white sand with bands of flint-conglomerate or breccia. Towards the south the sand runs to within 100 yards of the Isle of Purbeck Fault, but rests on Chalk dipping at no more than 10° northwards; towards the north it seems to rest on, or to be banked against decomposed Chalk, for the pits near its margin disclose merely a jumbled mass of unworn faults, from among which all matrix has disappeared. A second small outlier of sand, clay, and ironstone lies on a ridge in the Downs north of Swyre Head; it occurs in the line of the large mass described above, but is separated from it by a dry chalk-valley known as Scratchy Bottom.

Coombe Keynes, Warmwell, and West Stafford.

Turning northwards along the Tertiary base through Lulworth Park we find several swallow-holes in yellow clay and ferruginous grit 300 yards south of Shaggs, and a pit close by in which the Chalk dips due east at 5°. At Coombe Keynes there is a considerable thickness of red clay, which is dug for brick-making west of the village. It is associated here and there with flint-breccia and is overlain by a mass of pebble-gravel which forms Vary Clump, 400 yards S.E. of the Church. The long tongue on which Comb Wood stands, though it runs close up to the red clay, consists wholly of sand with flint-breccia and conglomerate here and there, and the same is the case at Wool, but at Winfrith the red clay comes in again and has given the name to Clay-pits Lane, where it was formerly dug.

At Warmwell, Bagshot Beds have been identified by Mr. Reid resting directly upon the Reading Beds, the London Clay having been abruptly overlapped. The base of the Reading Beds consists generally of sand with bands of ironstone, and beds of shingle together with large, partly rounded flints. Chert occurs abundantly. One and a half miles west of Warmwell a narrow tongue of Reading Beds runs about 500 yards into the Chalk area. The material is buff sand and shingle with large partly worn flints, some chert and rarely some quartz. It occupies a small valley which runs on for some 500 or 600 yards in the Chalk in a manner suggestive of its having been a hollow of erosion of pre-Eocene age, filled up with Tertiary sand and shingle. Throughout this neighbourhood, however, the upper surface of the Chalk is soft and much decomposed, and it is difficult to say how far irregularities in the strata lying upon it are due to "piping." Between West Knighton and West Stafford sand and ferruginous clay, with a trace here and there of red clay, rest upon the Chalk. Close upon this boundary comes an extensive sheet of Plateau Gravel, which effectually conceals the margin of the Bagshot Beds.

Tertiary Outliers; Bincombe, Blackdown, &c.

Among the numerous Eocene outliers upon the downs west of the Tertiary basin Mr. Reid has obtained remarkable evidence of the overlap by the Bagshot Beds, which he first noticed near Warmwell. In speaking of the changes undergone by the Bagshot Beds in their range through the Hampshire Basin, he says, "The Bournemouth Cliffs show a tendency to the increase of coarse sands, containing small fragments of black grit, lydite (or radiolarian chert), and occasionally of Greensend chert; splinters of flint also begin to appear. Coarse sands of this character continue to be associated with the pipe-clays westward to beyond Wareham. Then sets in a change like that undergone by the Reading Beds, but far more marked. The Bagshot Sands become coarser and gravelly, unworn flints and flint-splinters become abundant, and mixed with these is a quantity of subangular Greensand chert, like that occurring in the Reading Beds. There is, however, one character which enables us easily to distinguish between the Bagshot and Reading gravels. The Reading gravels consist of flint and chert, with an occasional quartz-pebble; careful search yielding nothing else except one or two small quartzite and grit-pebbles. Bagshot gravels, on the other hand, contain, besides flint and chert, so much quartz and hard subangular Palæozoic rocks as to make the finer screened material look like a Cornish beach. They yield also a certain quantity of Purbeck marble and other Purbeck rocks, though I have been unable to discover any trace of Portland Beds or of the Oolites below."*

By a recognition of these characters Mr. Reid has been able to show that all the outliers referred to belong to the Bagshot series, with the exception of a portion of a large patch at Little Mayne Farm, which consists principally of white sand, and of two small patches of white sand and red or yellow clay further south. This rapid overlap by the Bagshot series is accompanied by a rapid increase of coarseness in the gravels.

The most important of the outliers are that upon Bincombe Down and the cluster on Blackdown. The Bincombe outlier has been much dug for road-metal; it displays the irregular interbedding of gravel, clay, and sand usual to the Bagshot series, the gravel being in part a shingle of well-rolled flints, &c., with numerous small pebbles of white vein-quartz and other rocks, and partly subangular. The outlier extends to within 200 yards of the Ridgeway Fault, which tilts the Lower Chalk up at an angle of 85°, and a large gravel-pit open in 1855 shewed that the Tertiary beds also were nearly vertical. For the record of the section we are indebted to Mr. Fisher, who made the following notes:—The excavation was 24 feet deep, and the vertical strata occurred in the following sequence from north to south [which presumably would be in descending order]: sand and coarse pipe-clay, round gravel of flint pebbles, black inside; sand and clay; block of cherty grey flint, with numerous casts of fossils; subangular flint gravel, not ochreous, used for road metal.* Towards the northern margin, however, the Tertiary strata are either horizontal or only gently inclined, for the Chalk west of the outlier dips at only 14°, and east of it is nearly horizontal; the fact that their boundary, moreover, contours the ground shows that the beds are nearly flat.

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* *Quart. Journ. Geol. Soc.*, vol. lii., p. 491 (1896).

There is no doubt that both here and at Blackdown piping has been most extensive, but it is less reasonable to refer the extensive section noted by Mr. Fisher to that cause rather than to the well-known effect of the Ridgeway Fault, for it is a characteristic feature both of this and the Isle of Purbeck Fault that the strata on their northern sides pass abruptly from a vertical to a horizontal position. We may infer that this abrupt change of inclination traverses the centre of the Bincombe outlier, tilting up its south side, but leaving its northern half horizontal.

The distance from the margin of the Bagshot Gravels to the Lower Chalk seen in the Tunnel is insufficient to admit all the Upper and Middle Chalk, even supposing the strata to be all vertical. The absence of some part of the series may be due to compression and faulting such as occurs in Man-o'-War Cove, but on the other hand it is probably partly due to pre-Eocene erosion, the evidences of which grow stronger as we proceed westwards. Not only does the vast accumulation of rolled and unworn flints in the Bagshot series point to the destruction of much of the Chalk, but there seems to be an actual stratigraphical discordance between the two series, such as does not occur elsewhere in either the London or Hampshire Basins. (Plate VII., section 4).

The Blackdown outliers lie for the most part on nearly horizontal Chalk, but so far from conforming to the bedding of that rock, they run up and down the slopes of the hills, and though as a whole they occupy the high ground, yet at the highest point of all bare Chalk comes up to the surface. Part of the irregularity is certainly due to piping; some pits 100 yards south-west of the Hardy Monument shew stratified pebble-gravels dipping at 15°, 45°, and even 65°, while in another pit, 600 yards west of the monument, the gravel is partly vertical and partly horizontal. These dips are none of them due to earth-movements, but merely to the dissolution of the Chalk and the caving-in of the gravels.

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* *Geol. Mag.* for 1896, p. 246.

But on the other hand the occurrence of banks of shingle low down on the hill-side and of bare Chalk at its highest point can hardly be due to such a cause, unless we suppose that underground dissolution has proceeded on such an enormous scale as to carve the Chalk into hill and dale, and altogether alter the form of the surface on which the Tertiary beds were deposited.

Much of the Blackdown sand and gravel has been cemented into a sandstone-breccia or conglomerate as the case may be, and great blocks of these "greywethers" or "Sarsen stones" are scattered over the downs, especially on those parts which have been recently occupied by Tertiary strata in place. They show an obvious tendency, however, to travel down the steeper slopes, and congregate in the dry-chalk valleys. The bottom of the Valley of Stones to the east of Blackdown is dotted with them so thickly that it is possible to step from one to another for a long distance, while in the street of Portisham Village there are upwards of 60 great blocks within a distance of less than 200 yards. These masses frequently range up to 10 feet in length, and were invariably selected by the builders of cromlechs and stone-circles. Some thin slabs of ripple-marked grit, similarly hardened, occur on Bronkham Hill.

The discordance of the Bagshot Beds to the Chalk, though difficult to prove by stratigraphical evidence, is amply demonstrated by their contents. Mr. Reid finds that first in order of abundance are chalk-flints; next come fragments of chert resembling that in the Upper Greensand of Abbotsbury, usually subangular and of all sizes up to a foot in diameter; numerous small pebbles of vein-quartz, which may have come from Wealden strata; fragments of Purbeck limestone, with cherts and grits probably also of Purbeck age; and lastly subangular veined grits, hard sandstones, quartzites, quartz, radiolarian chert, and red and green jasper, all of which may have been derived from the Permian breccias of Devon. Budleigh Salterton Triassic pebbles are, however, entirely missing. From these facts he infers that the Bagshot gravels overlapped not only the Lower Eocene, but the whole of the Cretaceous group also, and thus came into contact with the older rocks.* The movements to which the overlaps in the Eocene strata were due will be described in another chapter.

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* *Quart. Journ. Geol. Soc.*, vol. lii., p. 493 (1896).

CHAPTER XIV.—PLEISTOCENE AND RECENT DEPOSITS.

Angular Flint Gravel of the Chalk Downs.

This is an irregular accumulation of flints in a matrix either of sand or gritty clay which overspreads the more level parts of the Downs within the area occupied by the Upper Chalk. It seems to correspond in its history to what is elsewhere called Clay-with-flints, and to be mainly the result of the removal or solution of Chalk-in-place. It is devoid of stratification and rests on an uneven surface of Chalk, often filling deep pipes in that rock. Its formation probably commenced as soon as the flinty Chalk was exposed to the air, and is doubtless now proceeding. This gravel, therefore, can be assigned to no definite age.

The Downs south and west of Dorchester are singularly free from this superficial deposit, but much of the Chaldon and Lulworth Upper Chalk area is overspread by it. On White Nothe especially the gravel can be well seen, cutting deeply yet so irregularly into the Chalk as to be scarcely mappable. On Flower's Barrow also the western end of a long narrow strip that runs along the Purbeck Hills touches the brow of the cliff.

Plateau Gravels.

Though spread so widely over the adjacent parts of Dorset, Hampshire, and the Isle of Wight, this deposit is represented only by the most insignificant patches in the Isle of Purbeck. One of these lies between Bucknowle House and West Bucknowle, and one mile south-west of Corfe Castle. Though not more than a couple of acres in extent, it presents the characteristic features of Plateau Gravel; it consists of a thin deposit of small angular flint-gravel resting on the nearly level top of an isolated hill of Wealden sands and clays, at some little height above the stream which drains the western part of the Isle of Purbeck, and at a distance of half a mile from the nearest Chalk-in-place. The gravel is dug to a depth of 3 feet for road-metal; but the supply is too small to be of much value. The patch closely resembles those which cap the low hills of Lower Greensand in the valley of the East Yar in the Isle of Wight. Like them it is obviously a remnant of a far larger sheet, which must have been spread before the present valleys had come into existence, but which has been in this case almost clean swept by denudation. Occasionally it is possible to prove that Plateau Gravels have been distributed along old lines of drainage, which coincided approximately with the existing river-courses. In the present instance all our evidence has perished, and we can only guess that the sheet originally extended along an old valley running from the west towards the gap in the hills at Corfe

Castle. By denudation of the whole area a small portion of the old surface has come to occupy the position of a hill in the present valley.

Another insignificant patch of gravel, made up of chert and limestone, rests on a gentle eminence of Kimmeridge Clay southwest of Encombe House. Bones of *Elephas primigenius*, *Rhinoceros tichorhinus*, &c., have been found near the house, but whether from this little patch of gravel or not does not appear.*

The gravels in the neighbourhood of Weymouth received much attention from Prestwich,† by whom the occurrence of nearly all those now to be described has been noted. Three hundred yards west of Osmington Mills a single small patch of flint-gravel occupies the highest point of the Corallian cliff, 160 feet above the sea. It extends along the cliff about 70 yards and reaches a thickness of 6 feet. The flints are almost angular, and but few other rocks occur. Somewhat similar minute outliers rest upon the Upper Greensand near Sandy Barrow. From their position we assume them to have a similar history to that of the small patch near Bucknowle.

At Broadway a more extensive outlier of flint-gravel occupies the flat top of the low water-shed of Oxford Clay between Lodmoor and the Wey. By the nature of the soil and form of the ground it has been mapped as extending nearly a mile in a north and south direction, but it is rarely seen, except in the railway-cutting, where it reaches a thickness of six feet. It lies at a height of 70 to 90 feet above the sea-level and contains a few pebbles derived from Tertiary Beds.

Three similar outliers occur at Furzedown. They consist chiefly of brown chert with some flints and a very few oval quartzite-pebbles from the Budleigh Salterton beds. The floor of Oxford Clay on which they rest stands at about 50 feet above the sea, but slopes down southwards towards the Fleet.

On Fleet Common there occurs a considerable deposit of chert-gravel with an occasional Budleigh pebble. It lies on Cornbrash at a height of more than 200 feet above the sea. Two other gravel-patches, also of brown chert, lie on the Fuller's Earth south of Langton Herring at a height of about 50 feet above the sea. These correspond in position and level with the patches at Furzedown and Broadway, rather than with that of Fleet Common. But here as elsewhere the Plateau Gravels are capricious in their mode of occurrence.

A few small patches of flint-gravel, with an occasional pebble from the Tertiary Beds, cap the highest of the low hills in the Oxford Clay tract north of Langton Herring. Though of no value, they are of interest as indicating how widely these gravel deposits must once have extended.

A great mass of gravel which overspreads the Downs north of Portisham and Abbotsbury must also be classed among the Plateau Gravels, although it occurs at heights ranging from 600 to nearly 700 feet above the sea. At its eastern end, where it lies upon the Upper Chalk, this mass is scarcely to be distinguished from the "Angular Flint Gravel of the Chalk Downs." It consists chiefly of such materials as might be derived from the dissolution of flinty chalk, together with an abundance of quartzite pebbles and pebbly-quartz sandstones (greywethers) from the neighbouring Tertiary Beds. Westwards, however, it gradually overlaps all the Chalk and passes on to the Upper Greensand, while a small detached portion occurs upon Forest Marble. Moreover, at its western end, though still conspicuously displaying its character as a plateau, yet by the denudation now proceeding it has been narrowed to a sinuous ridge ranging from 250 to less than 50 yards in width, and upwards of a mile in length. There it consists almost wholly of angular flints, with scarcely any Tertiary quartzite or chert, although it rests upon the Upper Greensand Chert Beds. The chert, however, is abundant in the small outlier on the Forest Marble. Clearly, therefore, this deposit has not resulted from mere atmospheric waste, nor has it been distributed over a surface bearing any resemblance to that of the present day. The plateau of which now so narrow a strip survives must have been of considerable extent, while the conditions under which it was overspread with the gravel have altogether changed. The only satisfactory explanation seems to be that the transport was effected during the Glacial Period when the freezing of the soil and a presumably heavy snowfall would bring into play forces different from those now in operation. The direction of the movement seems to have been approximately from N.E. to S.W., the distribution of the Tertiary boulders, the Chalk-flints, and the Greensand-cherts all favouring this conclusion.

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* *Quart. Journ. Geol. Soc.*, vol. xlviii., p. 277 (1892).

† *ib.*, vol. xxxi., p. 33 (1875).

For an account of some other deposits, which are no longer in existence or visible, we are indebted to Prestwich. "The Portland Mammaliferous Drift" was discovered in the Admiralty Quarries at a height of about 400 feet above the sea. It occupied a depression in the Purbeck rocks, and was from 10 to 20 feet thick and 50 to 60 yards wide, extending from N.E. to S.W. about 200 or 300 yards. It consisted of a red clay or loam, in places full of angular local *débris*, with a considerable number of blocks (some a quarter of a ton in weight) of Tertiary sarsen-stone. At a few places this was underlain by a singular layer of pebbles in a matrix of sand with a large proportion of manganese. In the lower part of the deposit were found:—

Elephas antiquus.
,, primigenius (?)
Equus.
Cervus.
Bos.

Damon records that quarrying operations in the Isle of Portland have from time to time disclosed accumulations of bones. In 1840, on the north-east side of the Island, the following were found and identified by Buckland and Conybeare:—Head bones of a large boar, *Bos urus*, deer, horse (an extinct species), wolf, dog, sheep, mouse. During the construction of the deep trench on the south side of the Verne Fort "numerous large fissures, some open at bottom but closed at top, and some entirely filled with *débris*, were met with, traversing the Portland Stone in a direction nearly north and south; and in the open ones . . . there were found numerous bones."* Among them Prestwich saw skull and bones of red deer, a metacarpal bone of *Cervus megaceros* (?), skull of *Bos longifrons*, and skull of dog. Damon records also *Cervus tarandus* (Reindeer) and *Bos urus*. They were thought by Prestwich to be of comparatively recent origin.

The occurrence of Upper Greensand-chert, chalk-flints, and blocks of Tertiary sandstone (sarsen-stone) in the gravel on Portland Island at a height of 400 feet above the sea, and the absence of such materials in the comparatively low-lying gravels near Weymouth and Broadway, led Prestwich into some interesting but erroneous speculations as to the age of the great topographical features of the district. He supposed the Portland gravel to have been deposited by a stream which flowed southward from the Greensand and Tertiary area and passed over Portland, at a time when the intervening low ground was bridged over by strata since removed; that is to say, that the denudation of the plain of Weymouth has taken place since the formation of the "mammaliferous drift of Portland." He further argued that the Broadway anticline, to which was due the denudation of the plain of Weymouth, was of the same age as the folds of Purbeck and the Isle of Wight, and concluded that "we thus obtain a marked instance of elevation and denudation during the Quaternary period."†

In attempting, however, to account for the composition of such gravels we have to consider the former distribution of the rocks from which they were derived. We now know that the Broadway anticline was of earlier age than supposed by Prestwich, for its crest was planed off before the Upper Greensand was deposited (p. 229). Further than this, it resulted from the early movements to which the Broadway anticline belonged that the Upper Cretaceous Rocks overlapped all the Oolitic and Lower Cretaceous formations in turn. Hence the fact that the newest rock now existing in Portland is of Lower Purbeck age by no means proves that the Chalk was far overhead; on the contrary, the Upper Cretaceous probably occupied the same relation to the Jurassic rocks of Portland as to those of White Nothe, and lay immediately on top of them. We need not therefore look so far as Ridgeway for the origin of the chert and flints, but may regard them as relics of Upper Cretaceous and Tertiary strata which once overspread the area where they occur.

The removal of the strata seems to have taken place in Miocene and post-Miocene times, for, as we shall show elsewhere, the drainage-system of this part of England was brought into existence by the series of earth-movements to which the Ridgeway, Ringstead, Purbeck, and Isle of Wight anticlines belong, and these earth-movements, though they commenced before the deposition of the Eocene, were chiefly accomplished in post-Oligocene times.

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* Prestwich, *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 30.
† *ib.*, p. 43.

The denudation in this particular tract has been accomplished therefore in two stages. Firstly, the inequalities caused by intra-Cretaceous folding were planed off by marine denudation prior to the deposition of the Upper Cretaceous Rocks. Secondly, the upheaval of the Upper Cretaceous Rocks led to their removal from broad tracts of the floor of older rocks, and thus exposed these older rocks to the action of the existing rivers. In dealing more particularly with the origin of the physical features we shall have occasion to point out that the courses followed by those rivers were not influenced in the slightest degree by the earlier folds, but were, on the other hand, directly determined by those of post-Oligocene date.

Raised Beach at Portland Bill.

The occurrence of this now well-known deposit of shingle, sand, and shells was first recorded by H. W. Bristow, in 1850, in a note on the Geological Survey Map. In 1852 Weston[*] referred to it as a marine shingle, and in 1860 Damon[†] noticed the occurrence in it of shells of species now living in the neighbouring sea. Mr. Whitaker,[‡] in 1869, was the first to apply the name of "raised beach," to trace the extent of the deposit, and to specify its contents, while, in 1870, Pengelly[§] pointed out that it contained pebbles from the Triassic pebble-beds of Budleigh Salterton. In 1875 Prestwich[||] included in his exhaustive description of the gravels of the neighbourhood of Weymouth a full description of this beach, with a more complete list of the shells contained in it and an account of the "head" which overlies it.

The shingle fringes the south-eastern margin of the island for about a mile. Its upper limit reaches a height of 65 feet above Ordnance Datum, and it slopes thence downwards to the brow of the low cliff which extends from the Bill north-westwards. Both in position and composition it differs from any deposit that could be formed now, even in the most abnormal state of weather.

The best exposures occur at the intersection of the inland margin of the beach by the coast-line, where its height above the sea-level impresses the observer with the changes that must have taken place since its formation. On the west side of the promontory it rests upon Portland Stone, and is banked against a low shelving cliff of the Purbeck Caps. The greatest thickness of gravel exposed is 12 feet, which are constituted as follows:—

		Ft.	In.
Roughly-stratified gravel, composed of subangular Portland Stone, Chert, and Purbeck Rocks; sometimes becoming a yellow clayey grit in the lower part	0 to	6	0
Well-stratified and well-washed shingle and grit, obliquely bedded	0 to	6	0
Purbeck or Portland Beds.			

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[*] *Quart. Journ. Geol. Soc.*, vol. viii., p. 117.

[†] "Geology of Weymouth and the Isle of Portland," 1st. ed., p. 141.

[‡] *Geol. Mag.*, vol. vi., p. 438.

[§] *Trans. Dev. Assoc.* for 1870, vol. iv., p. 201.

[||] *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 33. See also vol. xlviii., p. 277 (1892).

The gravel here referred to is of later date than the beach, and is probably a rainwash. The shingle, which is the actual beach, contains a few subangular lumps of Portland Stone, but the mass is made up of well-rounded beach-pebbles. The rocks occur in the following order of abundance:—

1. Flints and cherts, generally well-rounded. Most of them are decomposed and bleached to a depth of about an eighth of an inch, and at a distance look like white quartzites. Flints and cherts form about 90 per cent. of the pebbles.
2. White limestones ; many sub-angular, but some well-rounded.
3. Black hornstones, quartz-rock, &c. ; all small and well-rounded.
4. Black cherts.
5. Brown cherts ; not abundant.
6. Small fragments of Purbeck "beef."
7. Large partly-rounded lumps of ferruginous grit, derived either from Tertiary or Wealden Rocks.
8. A very few well-rolled oval quartzites, 3 to 4 inches long, resembling those in the Budleigh Salterton Triassic pebble-beds.
9. Granite boulders have also been recorded by both Pengelly and Prestwich.

Near its northern margin the shingle is cemented into a conglomerate by calcareous tufa, which, however, only partly fills up the interstices. Some small fissures in the underlying Portland Stone are filled up with shingle. The form of the beach, the proportion of sand and grit, and the angle of bedding in it show that the spot was not exposed to heavy surf, especially on the east side of the Island. A few shells only occur on the west side. On the east side of the Island at the Sand Holes, the beach consists largely of fine sand with many shells. The most abundant are *Littorina*, *Patella*, *Purpura*, *Ostrea*, *Mytilus*, many of which have the colour preserved. The list follows:—

Foraminifera.

Miliolina seminulum, *L.*
Polystomella striatopunctata, *F. & M.*

Ostracoda.

Cythere sp.

Bivalves.

Anomia ephippium, *L.*
*Cardium edule, *L.*
Cyamium minutum, *Fabr.*
Modiola marmorata, *Forbes.*
*Montacuta bidentata, *Mont.*
Mytilus edulis, *L.*
Ostrea edulis, *L.*
Saxicava rugosa, *L.*, var. arctica.
Tellina balthica, *L.*

Univalves.

Buccinum undatum, *L.*
Lacuna puteola, *Turton.*
Littorina littorea, *L.*
„ obtusata, *L.*
„ rudis, *Maton.*
Nassa incrassata, *Müll.*
*Natica.
*Odostomia (sp. indeterminable)
Patella vulgata, *L.*
*Bela (sp. indeterminable).
Purpura lapillus, *L.*
Rissoa parva, *Da Costa ;* and var. interrupta, *Adams.*
Rissoa striata, *Ad.*
„ subcylindrata, *Jeffreys*, sp. n.
Skenea planorbis, *Fabr.*
Tectura virginea, *Müll.*
Trochus cinerarius, *L.*
„ helicinus, *Fabr.*
„ umbilicatus, *Montagu.*
*Trophon truncatus, *Ström.*
Utriculus truncatulus, *Bruguière.*

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* Collected during the survey and identified by Mr. Clement Reid. The remainder of the list is taken from Prestwich's paper in the *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 33 (1875). Mr. Sykes records also *Bela turricula*, Mont., *B. rufa*, Mont., *Lacuna pallidula*, Da Costa, *Natica Montacuti*, Forbes, *Rissoa albella*, Loven. var. *Sarsii*, Loven. *Proc. Dorset Field Club*, vol. xvi. p. 178.

That this patch of shingle is a remnant of an extensive beach, and that it was formed when the coast-line was different to that of the present day, is obvious. The waste of land now in progress is due partly to the undercutting of the low cliffs of Portland Bill, but much more to the combined action of landslipping and waves along the east and west sides of the Island, where the Kimmeridge Clay rises above sea-level. By this process Portland Island has been reduced to the shape of a wedge pointed towards the south, but it must originally have been part of a long escarpment extending from near White Nothe westwards across West Bay, more or less parallel to the Jurassic escarpments of the Weymouth anticline. The raised beach seems to have been formed on the seaward slope of this escarpment when it was far more perfect than it now is.

The Chesil Beach.

This great shingle-bank commences near Bridport, and extends a distance of 18 miles to the Isle of Portland, where it terminates abruptly against the cliffs south of Chiswell. For the first six miles of its course it keeps in contact with the coast, but then for eight miles maintains a beautifully even curve at a distance of 200 to 1,000 yards from the main land, enclosing between itself and the shore a shallow salt-water and brackish lagoon known as the Fleet.* For the last two miles the beach strikes boldly out to sea to join itself on to Portland. It ranges in width from 170 yards at Abbotsbury to 200 yards at Portland, and in height from 22 feet 9 inches above high-water mark at Abbotsbury to 42 feet 9 inches at Chiswell. From Abbotsbury to Wyke it rises at the rate of 1 in 8,450 and from Wyke to Chiswell at the rate of 1 in 880. The shingle extends to a depth below Low-water Spring Tides of six fathoms at Abbotsbury, seven fathoms at Fleet, and eight fathoms at Portland, at which depth it gives way to sand. The stones of which the visible part of the beach consists increase in size from Abbotsbury to Portland, but those lying below Low-water Mark diminish in size in the same direction. Borings have shown that the shingle rests on its landward side upon a floor of clay at a depth of three or four feet above Low-water Spring Tides. The clay is said to have been exposed on the seaward side after storms, but it was not met with in the borings. It seems, therefore, to form a shelf upon the edge of which the beach is built. It is usually spoken of as Kimmeridge Clay, but a short length only of the beach actually stands upon that formation. The main part of the beach above High-water Mark is composed of loose shingle, which is always being shifted according to the changes of the wind, but the shingle below this is held in a matrix of sand and grit which is almost, if not quite, watertight. The tide, therefore, gains access to the Fleet at its eastward end only, by the narrow opening known as Small Mouth, and the rise and fall at Abbotsbury does not exceed a few inches and then only at Spring Tides, when a good deal of water leaks through the upper unconsolidated part of the bank.*

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* Fleet, Fleot, or Flot, Saxon for a shallow sheet of water.

In exceptional storms, however, the sea seems to have gained access somewhat freely to the Fleet. Leland, writing in 1546,† speaks of the south-eastern winds breaking through the bank,

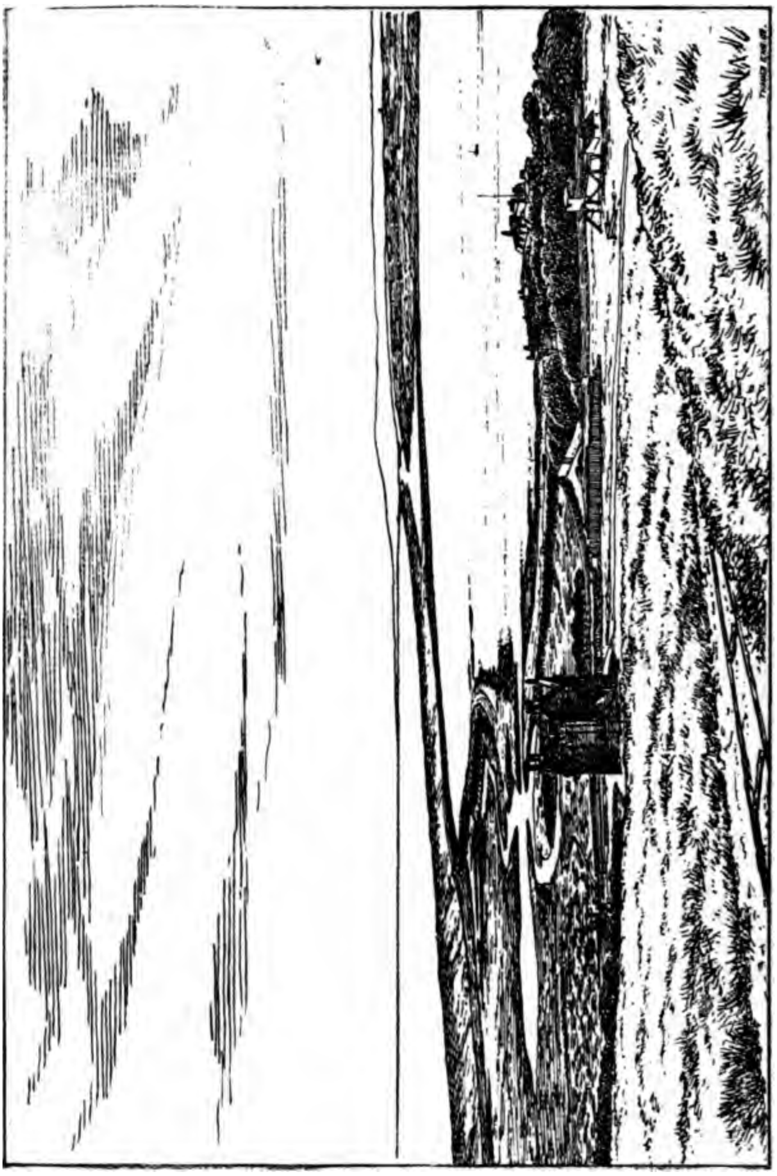

FIG. 180.—The Chesil Beach and the Portland Beach, from Portland Island. Drawn by H. W. G. WILLIAMS from a photograph.

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* The statistics here given are taken from Sir John Coode's paper in the *Proc. Inst. C.E.*, vol. xii., p. 520 (1853).

† Itinerary, vol. iii., p. 66.

and Camden, in 1590, says the Chesil Beach "when the south wind rises, gives and commonly cleaves asunder." Whatever this expression may mean, it is recorded that on November the 23rd, 1824, the sea-water stood to a depth of 22 feet 8 inches on the alluvial meadows at the Decoy, near Abbotsbury, this result having been brought about not so much by the giving way as by the overtopping of the bank by waves at high tide. In this same year the sloop Ebenezer, of 100 tons, ran on the crest of a wave so high up the bank that she was subsequently launched into Portland Roads. This occurred about midway between Ferry Bridge and Chiswell.

The deeply indented inner shore-line of the Fleet contrasts strongly with the monotonously even curve of the Chesil Beach. It has clearly never been exposed to the action of such a surf as breaks upon the bank, but presents rather the features characteristic of subaerial denudation, with but slight modification. Thus the effect of surf and tide upon such beds as here crop out would be to cut them all back impartially, the mass of the strata being soft clays, and the rock-bands insignificant. So far from this having been the case, the difference in hardness has been emphasised, and the Cornbrash and Corallian, the hard bands in the Forest Marble and some others form bold headlands, while such cliffs as exist are proportional in size to the miniature surf that arises within the Fleet. It thus has come about that the lagoon widens or contracts according to the nature of the strata cropping out in its northern shore. At Wyke it is contracted by the Corallian hills to a width not exceeding 200 yards, in the Oxford Clay outcrop it widens out to a maximum of 1,000 yards; the Cornbrash of Fleet hems it in again to a width of 250 yards, but in the soft Fuller's Earth outcrop it expands to 700 yards. Further north these outcrops are traversed in reverse order, and the Fleet after widening out in the Oxford Clay finally terminates at the Corallian escarpment west of Abbotsbury.

But though the Fleet, properly so called, ends here, similar features on a smaller scale extend towards the western part of the Chesil Bank at Burton Bradstock. Thus, half a mile east of Abbotsbury Coastguard Station there is a slight hollow between the beach and the hill-slopes. At and near the Station a little cliff of Fuller's Earth dominates the shingle, but 600 yards westwards a hollow recommences, which develops westwards into a low waterlogged flat upwards of 300 yards in width. The hollow is occupied by a grey alluvial clay, washed down from the adjacent slopes of Fuller's Earth, and doubtless was a small "fleet" until an artificial opening was cut in the Chesil Bank at the site of Swyre White House. One mile further west a similar hollow, partly silted up and partly still occupied by water, is known as Burton Mere. But at Cliff End, 15 miles from Chiswell, this feature of a hollow inside the Shingle Bank comes to an end, and thence for three miles the shingle is piled against the foot of a cliff of Oolitic clays and limestones.

Speculations as to the origin of the Chesil Bank have given rise to a voluminous literature. One of the first and the most exhaustive papers was that by Mr. (Sir John) Coode in 1853,[*] to which we are indebted for the measurements quoted above. In it he argues that the shingle has been derived from the coast between Lyme Regis and Sidmouth, that it has been transported by wind-waves, that the isolation of the bank is due to a bench of clay, that the larger size of the pebbles at the Portland end of the beach is accounted for by the larger pebbles being moved more readily than the small.

In 1869 Messrs. Bristow and Whitaker[†] attributed the excavation of the Fleet to the eastward deflection by the beach of the streams which descend to the shore eastward of Abbotsbury, thus implying that the beach was formed first and the Fleet subsequently. They pointed out "(1) that the isolated part of the bank is also the largest and strongest; . . . (2) that the very irregular shape and cliffless character of the shore of 'the Fleet' are not such as one would expect to be caused by the action of the sea along such a coast, whilst they are just what should be produced by the action of streams; and (3) that *the Channel ends where the streams end.*"

Mr. Fisher in 1873[‡] regarded the Fleet as the half of a submerged valley, and therefore as having been formed before the Bank.

In 1875 Prestwich argued:—[§]

"1st That the shingle of Chesil Bank is derived chiefly from the materials of the raised beach, of which a fragment still exists *in situ* on the Bill of Portland, and partly from the harder beds of the Portland and Purbeck formations of that island.

"2nd That the storm-waves . . . . drive the shingle . . . . on to the southern end of the Chesil Bank, whence it travels by the agency of wind-waves in a north-westerly direction. . . . .

"3rd That the growth of the Chesil Bank has been from south-east to north-west. . . .

"4th That the shingle of the 'raised beach' itself was formed of materials which had travelled direct from the coast of Devonshire. . . . .

"5th That the sea for a time passed between Portland and Weymouth, and that the Fleet is merely a portion of the old shore-line dammed out by the growth of the Chesil Bank.

"6th That the existing beaches are formed not only of the *débris* of the present coast, but also from shingle derived from old beaches, which, together with gravel of a former land-surface, is now scattered over various parts of the Channel bed. . . . ."

That the Fleet is the result of subaerial denudation as claimed by Messrs. Bristow and Whitaker, seems scarcely to admit of doubt. The draining of the Weymouth promontory (using this name to include the ground south of the Chalk Downs) is effected by a series of streams flowing southwards, and for the most part right across the intra-Cretaceous folds observable in the Oolitic rocks. Taken in order from east to west these streams are the Osmington Mill Brook, Preston Brook, the streams of Lodmoor, and the Wey.

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[*] *Proc. Inst. C.E.*, vol. xii., p. 520.

[†] *Geol. Mag.*, vol. vi., p. 433.

[‡] *Ibid*, vol. x., p. 481. *See also* Discussion on Prestwich's paper, *Proc. Inst. C.E.*, vol. xl., p. 83 (1875)

[§] *Proc. Inst. C.E.*, vol. xl., p. 60.

Passing up any of the streamlets which feed the Wey from the west we find ourselves in two or three miles on a low water-parting, beyond which the water descends westwards obviously towards another main stream. Such a stream no longer exists in its original form, but the position which by analogy we should have assigned to it, and to which the form of the ground points, coincides pretty closely with that occupied by the Fleet, which therefore cannot be better described than in Mr. Fisher's words as a "drowned valley."

On the origin of the pebbles of the Chesil Beach much light was thrown by Prestwich, who recognised that both the raised beach of Portland and the Plateau Gravels must have originally had a wide extension, and must have yielded a great mass of stones during their destruction. The pebbles occur in order of abundance as follows:—

Chalk-flints.

Greensand-chert.

Portland Limestone and chert.

Quartzites resembling those in the Triassic conglomerate at Budleigh Salterton, together with various other far-travelled rocks of doubtful source.

The occurrence of the quartzites has caused much speculation as to the power of waves and tides to roll pebbles along the sea-bottom, for it was assumed that they must have been brought direct from Budleigh to the Chesil Beach. Their presence, however, in the Plateau Gravels shows that they may have travelled at a far earlier date than was supposed and at a time when conditions were altogether different from those of the present day. The Plateau Gravels, it will be remembered, were not improbably contemporaneous with the Glacial Deposits of other parts of England, and themselves show indications of the action of ice. The Bagshot Beds, moreover, which, of course, must have extended over much, or perhaps all of the district, contain a variety of far-travelled rocks, and probably yielded much of the material of the Plateau Gravels.

The mapping of the Plateau Gravels show that there must have been at least two extensive sheets at different elevations on the north side of the Fleet, while a still more important deposit overspread the high ground at Abbotsbury. We may reasonably assume that these gravels were no less plentiful on the south side of the Fleet, and formed a source capable of having supplied both the raised beach of Portland Bill and its modern representative the Chesil Bank.

At the present day there are but few sources of shingle by which the beach can be fed. The patches of gravel near Fleet and Furzedown are separated from it by the Fleet, which the stones certainly cannot cross. Nor anywhere eastward of Abbotsbury is there any gravel, Chalk, or Greensand in such a position as to furnish *débris* to the shore. From that place westward however, long slopes of clayey ground, much given to landslips, lead up to the gravel-deposits of Abbotsbury Castle. This may have furnished much material before the denudation and landslips had removed so much of the gravels and Cretaceous Rocks.

As to the heaping up of the Chesil Bank in its present form, it seems to have been satisfactorily established that the pebbles travel from west to east, and not *vice versâ* as claimed by Prestwich. A large proportion of the gales that visit that coast, even if they commence in the south-east or south, veer to the west and north-west, so that the direction of S.S.W. assigned to the prevalent wind-waves is not strictly accurate. Moreover it has long been a matter of observation that wreckage travels eastwards on the beach, while lastly Sir John Coode and others state that the large pebbles always travel faster along a beach than the small, and that their gradation in size on the Chesil Beach therefore proves that the drift is towards the east. Against this Prestwich urges that there should be an overflow of pebbles at the east end of the beach, but it will be seen by the measurements quoted on p. 203 that the beach does actually attain its greatest height and width at that end. On the other hand, Prestwich indicates a point near Bridport where two beaches, by his theory, should meet, the Chesil Beach travelling westwards to meet the Bridport beach travelling eastwards. Here, if anywhere, there should be an excess of shingle, but as a matter of fact the beach at the point indicated is small.

The supposition that the pebbles get reduced by attrition during their passage along the Chesil Beach, involves the anomaly that though they could travel from Devon without being worn down, they could not survive the short passage from Portland to Bridport.

The fact seems to be that the beach, though oscillating from east to west according to the prevailing winds, systematically travels in one direction only, namely, towards the shore. The shelf of clay on which it rests is obviously the result of marine erosion. Whenever laid bare, as is reported to be the case in exceptional gales, it suffers erosion. At such times also the waves carry stones on to the top of the bank, and by a repetition of this process eventually roll the whole beach over upon itself. That the process is imperceptibly slow admits of no doubt, but that it must take place seems certain. It is, in fact, merely a continuation of the process of coast-erosion by which the sea has come to occupy the position it now holds.

In encroaching upon such an area the surf collects before it all the materials that are hard enough to survive. It thus happens that the beach at any stage in the process of encroachment represents the sweepings of the area that has been encroached upon, plus or minus the amount that has been carried away along shore. In this case an effectual barrier to the escape of the shingle is provided by Portland Island. The Chesil Beach, therefore, represents the accumulated gravels, &c., of the whole of the land-surface that once occupied West Bay.

It is worth noting that the landward slope of the Chesil Beach at Abbotsbury is partly overgrown and evidently but seldom disturbed, while at the Portland end there is no vegetation on any part of the bank. It would seem, therefore, that the beach is being rolled over upon itself more rapidly towards its eastern end, and is thus slowly swinging so as to assume the east and west trend which is general to the south coast. It must then have travelled along the west side of Portland Island, and at one time or another have joined that island at its southern extremity where the raised beach occurs. It might be inferred that the difference in level between the two beaches measures the movement of the land during the time that it has taken the Chesil Bank to travel from the Bill to its present position, a distance of 3 miles; but the case is not so simple, for there is abundant evidence in many parts of the coast that the land stood considerably higher in Neolithic times than it does now (p. 234). The upward movement, therefore, has not been continuous, but oscillatory, and the Chesil Bank must either have been raised above the reach of the waves in Neolithic times or been formed since that period. Of its position and form in the Neolithic period we have no evidence.

The Portland Beach.

We use this name to distinguish from the Chesil Bank a small beach of strictly local origin. It starts at Portland Castle and runs north-westwards to join the Chesil Beach at 1,200 yards distance from the Railway Station; it then, after running alongside of, and in contact with the Chesil Bank for 800 yards, diverges towards the north and ends at Small Mouth (Fig. 180). The road and railway are carried along this latter part of it, and to it is due the narrowness of the outlet of the Fleet. This bank also shuts in a "fleet," a triangular mud-flat covered at high-water, and known as The Mere, the other margins being formed by the Chesil Bank and the north-western corner of Portland Island; the outlet is a gap in the Portland Beach 300 yards west of Portland Castle.

The stones composing this bank are mostly sub-angular or angular, and consist entirely of fragments of Portland and Purbeck Rocks. They must have come from the east cliffs of the Island and have travelled northwards, and even north-westward, to their present position, a course which is easily understood when the effect of the Portland peninsula on the run of the waves is taken into account.* It is interesting to note that this and the Chesil Beach, though in contact, do not mingle. Walking along the little valley between the two banks we have on the one hand chert - and limestone - *débris* travelling north-westwards, and on the other pebbles of flint, chert and quartzite travelling south-eastwards, the bottom of the depression sharply marking the division between the two. The building of the Portland Breakwater has probably put an end to the growth of this Portland Beach.

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* With a south-westerly, or even westerly, wind the waves approach the Weymouth beach from the south-east, having been gradually deflected from their course during their passage round Portland Island.

The Weymouth Beach.

This beach extends from Weymouth north-eastwards for about two miles, and like the other shingle-banks described above, more or less dams up the land-water on the low-lying tracts behind it. One of these tracts, known as Weymouth Backwater, is the estuary of the Wey, and was fully open to the tide until a dam was carried across it to prevent the laying bare of the mud at low tide. The beach extends for about three-quarters of a mile across its mouth, and forms the site of the part of Weymouth known as Melcombe Regis. The other tract referred to is known as Lodmore, and seems to have been due to the degradation of the soft Oxford Clay; the drainage from it is carried under the shingle-bank by a tidal sluice. It is reported that the shingle-bank, by which alone this marsh is protected from the sea and along which a high road and the water-mains are carried, has seriously diminished in size since the building of the Portland Breakwater.* In the Weymouth beach the stones are larger in the central and north-eastern parts of the beach than at its southern end, where it passes into sand.

Calcareous Tufa.

Near Blashenwell Farm a rudely elliptical area, measuring about 500 yards by 220 yards in its widest part, is occupied by a calcareous tufa. This deposit was first described by Mr. Mansel-Pleydell (then J. C. Mansel),† and by the Rev. J. C. Austen,‡ but more recently has been made the subject of an exhaustive examination by Mr. C. Reid.§ It has obviously resulted from the deposition of lime by a spring which drains the narrow synclinal trough of Upper Purbeck strata running from Blashenwell past Lynch for nearly a mile. The spring rises in the Middle Purbeck, and passing over the gentle slopes underlain by the Upper Purbeck and Wealden strata has given rise to the broad deposit alluded to. The deposition of lime in such cases is due to the escape of carbonic acid gas from a spring-water containing the bicarbonate of lime in solution, a process which is partly due to evaporation, when the water spreads itself on a gentle slope, but principally perhaps to the action of plants. The less soluble carbonate of lime thus precipitated repeatedly blocks the channel of the stream and leads to the lateral growth of the deposit. The spring in this case, as in many others, seems to be less rich in lime than formerly, and the formation of tufa has long since ceased. The greatest depth observed was nine feet.

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* See also Damon. *Geology of Weymouth*, 1884, p. 155.

† Papers read before the Purbeck Society, pp. 120, 175, and *Proc. Dorset Field Club*, vol. vii., p. 109 (1886).

‡ *Ibid.*, p. 124.

§ *Proc. Dorset Field Club*, vol. xvii., p. 67 (1896).

The best section occurs in a pit 250 yards north of Blashenwell Farm, and is recorded by Mr. Reid as follows:—

	Ft.	In.
Black soil: at its base Roman coins, Romano-British pottery, shells of oyster, whelk, cockle, *Helix aspersa*, *H. ericetorum*, *H. virgata*, &c.	1	0
Hard tufa with leaves of hazel, elm, and oak, land-shells, flint flakes, bones of pig and deer, limpets and other marine shells, land-snails, including *Clausilia laminata*, *Bulimus montanus*, &c., much charcoal	8	0
Loamy and marly tufa, with small land-shells, occasional *Limnæa truncatula*, rare flint-flakes, and charcoal		
Loam with stony base		

The deposition of tufa had ceased before the formation of the Roman layer, and before a grave, believed to have been of Neolithic age, had been dug. The flaking of the flint in the tufa was of the ordinary Neolithic type though poorly done; a few of the specimens, however, showed an extremely minute secondary flaking which is now believed to characterise a definite stage in Neolithic history. Extinct mammals, domestic animals, cultivated plants and pottery were entirely absent, but bones of pig red-deer, roe-deer, and a large ox used for food were found together with much charcoal. The absence of the cockle, oyster, and whelk, and the abundance of broken shells of *Patella vulgata*, *Littorina littorea*, *L. littoralis*, *Trochus tumidus* and *Scrobicularia piperata* led Mr. Reid to believe that the tribe gathered their shells for food in the neighbourhood of Chapman's Pool.

The land and freshwater shells in the tufa were all of species still inhabiting Dorset, but the absence of the three commonest snails of the present day, except in the Roman layer, was noteworthy. The complete list is as follows:—

Limnæa truncatula (rare; the only freshwater species).
Hyalinia cellaria (abundant).
„ nitidula.
„ crystallina (common at the base, rare above).
„ fulva (one).
Helix aculeata (rare).
„ nemoralis (abundant).
„ hortensis (abundant).
„ arbustorum (common).
„ hispida (common).
Helix granulata.
„ rotundata (abundant).
„ pulchella (one).
„ lapicida (rare).
Bulimus montanus (rare).
Pupa umbilicata (one).
Vertigo pusilla (one).
Clausilia rugosa (common
„ laminata (rare).
Zua lubrica (rare).
Carychium minimum (common).
Cyclostoma elegans (abundant).

CHAPTER XV.

DISTURBANCES AND FAULTS.

Introduction.

In a previous Memoir[*] we have referred briefly to the more prominent of the anticlinal and synclinal folds, of which those in the Isle of Wight and the Dorset coast form part. It was there pointed out that in the south of England the three great synclines of London, Chichester, and the Solent are separated by the three equally important anticlinal axes of Guildford, Portsdown, and the Isle of Wight; that the anticlines all have these properties in common, namely, that the northern side of the arch is always much steeper than the southern; that each anticline is in reality an elongated dome and each syncline an elongated basin; and lastly that these domes and basins are arranged *en échelon* along a line running about E. 10°—15° N., that is approximately parallel to the chalk-escarpment between Dorset and Norfolk. All these folds, there is reason to think, were produced during Tertiary times, for we have evidence that they commenced in the Eocene, culminated in the Miocene, and continued even as late as the Pliocene period.

In our present district we have to deal with a series of folds belonging to this late age and presenting the same characteristics as those referred to above, though in a more intense form; but there is this additional complication, namely, that they were here superimposed upon an older series of faults and folds having nearly the same direction. In describing the stratigraphy of the region we have already shown that these earlier movements took place after the deposition of the Jurassic strata of the Wealden and not improbably of the Lower Greensand, and that in the part of the area affected by them they led to a great unconformity at the base of the Upper Cretaceous Rocks. The two sets of disturbances may thus be conveniently grouped as intra-Cretaceous and post-Cretaceous.

The distinction between the two sets is generally easy where Upper Cretaceous and Jurassic rocks both occur, the superposition, for example, of horizontal Upper Greensand upon highly inclined Oolitic strata enabling us at once to assign the disturbance to the earlier age; and though there are some folds in the older rocks to which this test cannot be applied, even of these it is possible to infer the date with considerable probability. In describing the disturbances we take the post-Cretaceous movements first, and subsequently deal with the earlier set and the few doubtful cases.

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[*] *Geology of the Isle of Wight* (Geological Survey Memoir), 2nd Ed., 1889, chap. xiv.

POST-CRETACEOUS DISTURBANCES.

The post-Cretaceous disturbances include the following:—

1. The Isle of Purbeck Fault and Anticline, which extends from Ballard Point to the coast near West Lulworth, where it passes out to sea.
2. The Ringstead Fold—a comparatively small disturbance, about a mile in length.
3. The Ridgeway Fault and Anticline, including the Chaldon Anticline. This is second in importance only to the Isle of Purbeck Fault. It commences in a sharp anticline near East Chaldon, is temporarily interrupted near East Holworth, but thence westwards rapidly gains intensity, until it disappears between Portisham and Abbotsbury.
4. The Litton Cheney Fault, which extends about a mile on either side of the village of that name.*

It will be noticed that these disturbances succeed one another *en échelon* in a direction about W. 19° N., instead of W. 10° to 15° S., as was the case with those of the East of England and Hampshire. We have already remarked that the line along which the East of England and Hampshire disturbances are arranged runs not far from parallel with the great Chalk Escarpment across England. Here in the south-west, where the disturbances are arranged in a different direction, there is a corresponding change in the escarpment of Upper Cretaceous Rocks. For this feature, after keeping a fairly regular course through Berks, Wilts, and Dorset, then makes a great sweep to the west, so as to include a large part of Devon.

That the post-Cretaceous movements took place in great part after the deposition of the Hamstead Beds (Middle Oligocene) has long been known from the fact that those strata share in the uplift in the Isle of Wight, but there was nothing in that region to suggest that they had commenced in earlier Tertiary times.† One of the results, however, of the detailed mapping of the Tertiary area of Dorset by Mr. Reid has been to show that there is not only an overlap of the Lower by the Middle Eocene (Bagshot Beds), but that there is evidence of denudation of the Upper Cretaceous Rocks having taken place before and during Eocene times on such a scale as to prove great upheaval.‡ The evidence consists in the composition of the gravels. The gravels of the Reading Series were found by Mr. Reid to contain Chalk-flints and Greensand-chert, from which he infers that erosion following upon upheaval, had removed all the Chalk from some part of the area and laid bare Upper Greensand. In the Bagshot gravels, in addition to the above, he found chert of Purbeck age, from which he infers that further upheaval had led to the removal of all Cretaceous Rocks from some part of the area and laid bare the Purbeck, at the same time that it led to the unconformable overlap of London Clay, Reading Beds, and Chalk

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* The Winterborne post-Cretaceous movement falls only partly within the area described in this memoir, and is not included in the above list.

† *Geology of the Isle of Wight* (Memoirs of the Geol. Survey), 2nd ed., p. 242 (1889).

‡ *Quart. Journ. Geol. Soc.*, vol. lii., p. 490 (1896).

(in part) which his mapping has shown to exist. Lastly came the folding of Miocene age, which affected all the Hampshire Tertiary strata and continued during early Pliocene times, as proved by the situation of the Lenham Beds.[*] We thus divide the post-Cretaceous movements into at least three distinct steps:—

1. Between Chalk and Eocene.
2. Between Lower and Middle Eocene.
3. Miocene and Early Pliocene.

(1) *The Isle of Purbeck Fault and Anticline.*

Ballard Point (Plates IV., VII., and XI.).

There cannot be much doubt that this disturbance is the same as the Brixton anticline of the Isle of Wight. The Needles and Scratchells Bay can be seen from many points in the Chalk-hills of Purbeck to lie exactly in the line of the fault. Nor is there any essential difference in the structure of the two localities; in both the strata in the northern limb plunge down at extremely steep angles, while in the extreme southern points of the Isle of Purbeck we can see, as in the Isle of Wight, that the strata are beginning to assume the gentle southerly dip characteristic of the southern sides of these anticlines. In the Isle of Purbeck, however, the disturbance has proceeded a step further than anywhere in the Isle of Wight (excepting only in the doubtful case of Asheyf[†]), and the rocks are not only bent but faulted in a remarkable manner.

The fault alluded to has long formed an object of interest when viewed, as it can only be, from the sea, and was admirably described and figured by Webster in 1816.[‡] The accompanying view (Plate IV.) is from a photograph by Prof. H. E. Armstrong taken at extreme low spring-tide. The spot lies between Ballard Point and the Foreland, off which stand the Chalk-pinnacles known as Old Harry and Old Harry's Wife. From the Foreland to the fault the cliff consists of Upper Chalk with flints, dipping at a gentle angle northwards, and passing, in Studland Bay, under the Tertiary Beds of the Hampshire Basin. But from the fault southwards, to beyond Ballard Point, the strata are vertical or nearly so. The horizontal strata, as they approach the vertical series, turn upwards in a great curve, forming nearly the quarter of a circle. A fracture has taken place, exactly following one of the curved bedding-planes, and the curved and gently inclined beds have been pushed bodily over the edges of the vertical beds, so as now to rest upon them with an appearance of an extreme unconformity. The bedding of the vertical strata seems at a distance to be regular, with the lines of flint in their usual condition. But on a closer view the chalk presents manifest signs of pressure. The flints are not only broken to fragments, but the fragments are more or less separated from one another, while the entire mass of chalk is traversed by veins of calc-spar, and by planes of slickenside filled in with secondary flint, and has been hardened to the consistency of limestone, as described on p. 168.

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[*] *Pliocene Deposits of Britain* (Memoirs of the Geol. Survey), p. 69 (1890).

[†] *Geology of the Isle of Wight* (Geol. Survey Memoir), 2nd Ed., p. 241.

[‡] Englefield's *Isle of Wight*, pp. 164-168, Pl. 26 and 27. *See also* Conybeare and Phillips, *Outlines of the Geology of England and Wales* (1822), pp. 111, 112; W. B. Clarke, *Mag. Nat. Hist.*, new ser. vol, i, p. 461; Buckland and De la Beche, *Trans. Geol. Soc.*, Ser. 2, vol. iv., pt. 1 (1835), p. 1; C. H. Weston, *Quart. Journ. Geol. Soc.*, vol. iv., p. 245 (1848), and vol. viii., p. 110 (1852); J. Prestwich, *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 43 (1875); C. Barrois, *Terrain Crétacé Supérieur*, 1876,; A. Strahan, *Quart. Journ. Geol. Soc.*, vol. li., p. 549 (1895).

These alterations have been effected principally in the chalk below the curving fault, and in the curved beds close to it, the rock above being but little changed. Parallel to the principal fracture there run many small cracks filled with solid flint or lined with flint but hollow in the middle. The shattering of flints is more especially noticeable near these cracks, as well as near the principal fracture. The whole of the chalk, however, has been more or less broken and reconsolidated, so that much of it might be described as fault-breccia. It is worthy of remark also that there is a number of joints or cracks springing nearly at right angles downwards from the principal fracture; though not particularly noticeable here, fractures having a similar relation to the main line of fault become an important feature near West Lulworth.

Webster*, in 1812, was the first to attempt an explanation of the structure of the chalk in this cliff. He suggested that the curved strata were originally deposited against a bank consisting of the strata which are now vertical, and that the whole were subsequently elevated and bent. Conybeare and Phillips, in 1822,† accounted for it by assuming that a fault with a low hade, and coinciding in parts of its course with the lines of stratification, was formed after the monoclinal fold had come into existence. By movement along such a fault the vertical portion of the monocline might be brought under the horizontal or curved part; but the movement must have been in the reverse direction to that of a normal fault, which they do not seem to have noticed.

The Rev. W. B. Clarke, in 1837,‡ supposed the fracture and elevation of the chalk to have been accomplished simultaneously. A crack having been formed diagonally across the early horizontal strata, the block below the fracture was elevated and inclined, while the block above remained horizontal, but eventually curved upwards by a continuance of the elevatory process.

That such an unconformity can exist in the middle of the Upper Chalk as that supposed by Webster, is contrary to all experience; the superposition of the curve on the vertical strata is beyond all question due to a fault. Nor can it be doubted that the fault and the fold originated in the same earth-movement, for the sliding of one bed over another is an inevitable result of folding in such strata,* and fracture ensues at the stage when folding can no longer afford relief to the strain.

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* Englefield's *Isle of Wight*, p. 218.

† *Outlines of the Geology of England and Wales*, pp. 111, 112.

‡ *Mag. Nat. Hist.*, new series, vol. i., p. 461.

It so happens that the South Coast provides us with four stages in the production of such a fault and fold as that of the Isle of the Purbeck. Firstly, in the Isle of Wight, we have the simple monocline, for so the northern limb of one of these anticlines may be termed; secondly, at Swanage the monoclinal fold is accompanied by a fracture which has taken place partly along the bedding-planes, and partly across them; thirdly, at Lulworth the monocline is complicated by minor undulations, much movement having taken place along bedding-planes, and large masses of soft rocks having been squeezed out from a part of the fold where compression was great, and packed away elsewhere; fourthly, at Durdle, where the strata in the central portion of the monocline have been forced considerably past verticality, at the same time that partial relief was afforded by two types of fracture not seen elsewhere, namely, the approximately horizontal slide-planes, and the vertical belts of crushed rock. Lastly, common to all localities is the compression undergone by the more plastic beds, and which increases steadily westwards to a maximum at Durdle, where about 1,000 feet of strata are crowded into about a quarter of their true thickness (p. 179).

Though the Isle of Purbeck Fault intersects the cliff again west of Lulworth, its form is clearly shown in Ballard Point only. Here we may ascertain the following facts:—

1. The strata above it are bent into a curve, obviously forming part of the monoclinal structure which was the first stage in the disturbance.
2. The fracture follows the bedding of the strata above it, but cuts across the bedding of those below.
3. The strata above the fracture have been pushed southwards relatively to those below, and then over them.†

These observations lead to the inference (1) that the fault came into existence when the folding had already reached the stage exemplified in the Isle of Wight; (2) that it followed the bedding in part of its course, namely, where the strata turn up to the south on approaching the fold, but that it cut across the bedding in the central part of the monocline, where the strata were vertical; and (3) that that part of the chalk in which the fracture followed the bedding has been pushed bodily over that part in which it cut across the vertical bedding. Hence resulted the curious imitation of an unconformable superposition of curving and gently inclined strata upon the edges of vertical beds, which deceived Webster.

The course followed by the fracture seems to have resulted naturally from the form of the fold. Had it followed the bedding throughout the double curve of the ƨ, movement along it would have been impossible. On the other hand, that it should coincide with the bedding in part of its course was inevitable under the circumstances, and it would naturally follow as far as possible these already existing divisional planes in the rock.

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* The sliding referred to can be admirably illustrated by bending a paper-book and observing the distortion produced in any design drawn across the edges of the leaves.

† The movement along the fracture has therefore been the reverse of that of a normal fault, and it may be remarked that reversed faults result from the compression of strata, whereas normal faulting increases the superficial area occupied by rocks in proportion to the hade of the faults, and presumably results from an extension of space being afforded by earth-movements.

The fact that the part of the monocline in which the fracture coincided with the bedding has been shifted on to that part in which the beds are vertical gives a clue to the extent of the movement. On inspection of the section (Plate VI.) it will be seen that the vertical strata below the fault must curve round at no great depth below the sea, until they become parallel to the fault and eventually run into it, thus completing the monoclinal structure; and further, it may be presumed that the curving strata above the fault were brought up from the point where that parallelism takes place, the exact distance depending on the sharpness of the fold. The section as drawn indicates that the displacement amounts to about 400 feet, but if the vertical strata do not turn so sharply as represented this distance would be greater. It must be remembered, however, that the vertical strata under the fault have been identified as the uppermost zone of the Chalk; if, therefore, they do not turn as shown, we must suppose that Tertiary beds succeed them in due course under the fault. It is true that this newest Chalk is actually surrounded on every side by older rock, and theoretically it is equally possible for a mass of Eocene strata to be similarly enclosed. But it would mean that the fracture must originally have left the Chalk and passed out into the Tertiary rocks, which is not probable.

The upward curve of the fault above the top of the cliff is shown as cutting across the bedding in consequence of the difficulty of supposing that sliding could take place along a double curve, as explained above. The movement probably diminished both upwards and downwards, and eventually died away in the less disturbed chalk both north and south of the fold.

Worbarrow and Mupe Bays. (Plate X.)

The Worbarrow cliffs show the Wealden and Upper Cretaceous Rocks all bending over northwards, with a dip that steadily increases as they approach the fault, till it reaches 60°, but we get no view of the actual fracture, even in the deep bight of Arish Mell. The same is the case in Mupe Bay, where, however, the dips range from 70° and 75° in the Wealden Beds up to 85° and 90° in the Chalk Rock. Between Mupe and Worbarrow Bays the Isle of Purbeck Fault changes direction from W. 18° S. to W. 2° N., and thus becomes parallel to the Ridgeway and Chaldon folds. As a result of the change the Chalk Rock outcrop of Mupe Bay would, if prolonged, strike the Lower Purbeck outcrop of Worbarrow Tout, more than half a mile south of its actual position in Worbarrow Bay. The other strata show a similar deflection.

Lulworth Cove. (Plates VII. and X.)

The structure of the east side of Lulworth Cove is illustrated by (Section 2, Plate VII.), which, however, has been reversed to facilitate comparison with the others. Here the increasing energy of the movement is shown by inversion, accompanied by great compression and contortion of the more yielding strata. Thus the lower beds of the Wealden are turned over 20° beyond verticality, although the Portland and Lower Purbeck strata dip normally to the north at 20° or 30° in the East Point. As a consequence, the Wealden, with an apparent dip of 70° to the south (or true dip of 110° to the north), stand almost at right angles to the Lower Purbeck, and would meet them at about 100 feet below sea-level, if prolonged in that direction. Here, therefore, is indicated a region of compression. Upwards, on the other hand, the equally rapid divergence of the two groups points to a region in the monocline where there was a tendency to gape,* and in that region we have an admirable exhibition of the power of soft strata to accommodate more massive rocks above and below them. A small but very sharp anticline appears first at the foot of the cliff in the Cinder Bed, and at the same time the softer beds are squeezed out, so that all the rock-bands lie closer together than they ought to. In the cliff above, the little anticline gains size in every succeeding zone, until it becomes a large inverted V in the Unio Beds, while a number of well-known horizons, which were absent in the series in the foot of the cliff, begin to take their proper places. The effect of the V is that a length of bedding-plane originally amounting to about 200 feet has been packed into a length of about 100 feet, and the strata thus packed away can only be those which were squeezed out of the region of compression down below. The well-known contortions of the Upper and Middle Purbeck Rocks of Stair Hole seem to have originated in the same way, though there is nowhere seen so perfect an oblique V as at Lulworth.

The form of the V, taken in connection with the above considerations, points to its having been formed by a ruck-up from below upwards. The hinge-like movement of bed over bed which accompanies all folding must have led to the Wealden Beds travelling upwards on the Purbeck in this part of the monocline, and the ruck-up was doubtless partly due to movement of this character. Parts of the Upper Purbeck, as may be seen by the dimensions given above, must have moved 100 feet relatively to the Lower Purbeck, and this apparently not along any one fracture, but by sliding along a number of bedding-planes.

The inversion seen in the Wealden diminishes northwards, and the Greensand and Chalk dip in the normal direction at only about 45°, but there is no doubt, though there are no sections to prove it, that the dip increases again in the upper beds of the Chalk. Hence results the undulation in the monoclinal curve depicted in the section. It is, indeed, not certain that there is a fault here comparable to that of Ballard Point, for we only know that Tertiary beds succeed nearly vertical Chalk along a line having the proper direction, but, on the other hand, they are the lowest Tertiary rocks, and they rest against what must be nearly, if not quite, the topmost beds of the Chalk. The position can be explained by an extremely sharp fold, bringing the strata from verticality to horizontality in a few yards.

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* By again employing a paper-book and bending it into the form of an S the region of compression and the region of gaping in the monocline can be well illustrated.

Between Lulworth Cove and Dungy Head the Upper Greensand and Gault do not appear at the surface, though they are seen at both those places. Their absence is due to a crush-plane which brings Chalk against Wealden for a distance of 700 yards, and then disappears, both eastwards and westwards, in a mass of vertical Wealden sands and clays. A second parallel crush-plane runs between the Wealden and Middle Purbeck at Dungy Head, and squeezes out the Upper Purbeck, while a third brings the nearly vertical Cinder Bed into contact with Lower Purbeck and Portland strata, dipping at a high angle. These crushes can be recognised by the fact that certain well-known horizons are missing, but probably a large number of others remain undetected in the mass of the Chalk and the Wealden Beds.

The strata from the Cinder Bed upwards are vertical or nearly so, but the Upper Chalk is slightly inverted, and in Man-o'-War Cove is turned over 30° beyond verticality. Along the foot of the cliff there runs a nearly vertical rib of crushed chalk, pretty closely following the horizon of the Chalk Rock as described on p. 179; it is particularly well seen in a recess of the cliff north-east of the eastern end of the Man-o'-War Rock, where the view forming Plate V was taken. The walking-stick indicates a flint which has been not only crushed into powder, but drawn out into a black streak; other flints close by are broken but not disarranged, and some not even broken. The compression hereabouts has been so great that a thickness of 1,000 feet of strata has been compressed into 250 feet, as already noted.

Man-o'-War and Durdlé Coves.

In these coves a type of slide-plane not hitherto met with makes its appearance. The planes slope down southwards at 10° to 20° and thus cut obliquely across the inverted bedding. They occur at irregular intervals one above the other, and in every case the roof has moved northwards and upwards over the floor, a distance varying from 4 to 12 feet, and possibly more. One of the slides in which the movement has been 7 feet occurs towards the eastern part of Man-o'-War Cove. Two more can be seen in the Marl Bed (zone of *Belemnitella plena*) in Durdle Door Cove, and a fourth runs near the foot of the cliff for about 200 yards, its course marked out conspicuously by a line of caves. The part played by these slide-planes in the general structure is illustrated by Plate IX. The upper limb of the ƨ was being forced northwards, and had already reached the stage at which the strata in the central limb were inverted. Relief from the strain was obtained in three ways: (1) by compression of the softer rocks and their removal to regions of less compression, as at Lulworth; (2) by the crushing of vertical belts of chalk ; (3) by the fracturing of the rock in a nearly horizontal direction, and by the thrusting of the roof of each fracture over the floor northwards, this last structure seeming to mark the point at which inversion ceases and over-thrusting commences.

Swyre Head.

In Swyre Head and Bat's Head the cliff is too steep to admit of examination. Some small inaccessible caves arranged along nearly horizontal lines suggest other slide-planes such as have been just described. At Bat's Head the lowest horizon seen is above the Chalk Rock, and the whole series is exactly vertical; the Portland Stone outcrop is marked by the rock known as the Cow, and lies at 115 yards distance from the outer face of Bat's Head. The compression here, therefore, is much the same as at Man-o'-War Cove.

The Isle of Purbeck Fault cuts through the cliff 500 yards west of Bat's Head, but so obliquely that it is difficult to interpret the section. The chalk continues to stand vertically close up to the fault. The actual fracture is lost in a belt of shattered chalk about 50 yards in width with slickenside which shoots through it in every direction, but principally east and west, with a slant down northwards, though many friction-grooves run down at a gentle angle westwards also. On the north side of this shattered belt the dip is 35°, and falls in 150 yards to 0°—which, allowing for the obliquity of the section to the fault, means that the strata become horizontal at about 30 yards distance from the fault. In another 150 yards a south-easterly dip of 20° to 30° sets in and continues for more than half a mile. There are several small slips in this cliff, which are more like the slide-planes of Durdle Cove than normal faults. Four of these occur in succession, all ranging about north or north-east, and sloping down eastwards at angles ranging from 10° to 30°; but there is nothing to shew what movement has taken place along them.

Here we see the last of the great Isle of Wight and Purbeck fold, for no trace of it exists in the Weymouth promontory. It must therefore die away rather abruptly in Weymouth Bay, not very far from the area where it attained its greatest intensity. In accordance with the general rule, simultaneously with the disappearace of this fold, there commences the similar fault and anticline of Chaldon and Ridgeway, together with a small intervening disturbance at Ringstead.

Before quitting the Isle of Purbeck fault, however, we may mention that the faults in the Jurassic rocks of Purbeck are probably all of post-Cretaceous age, for in that region there is

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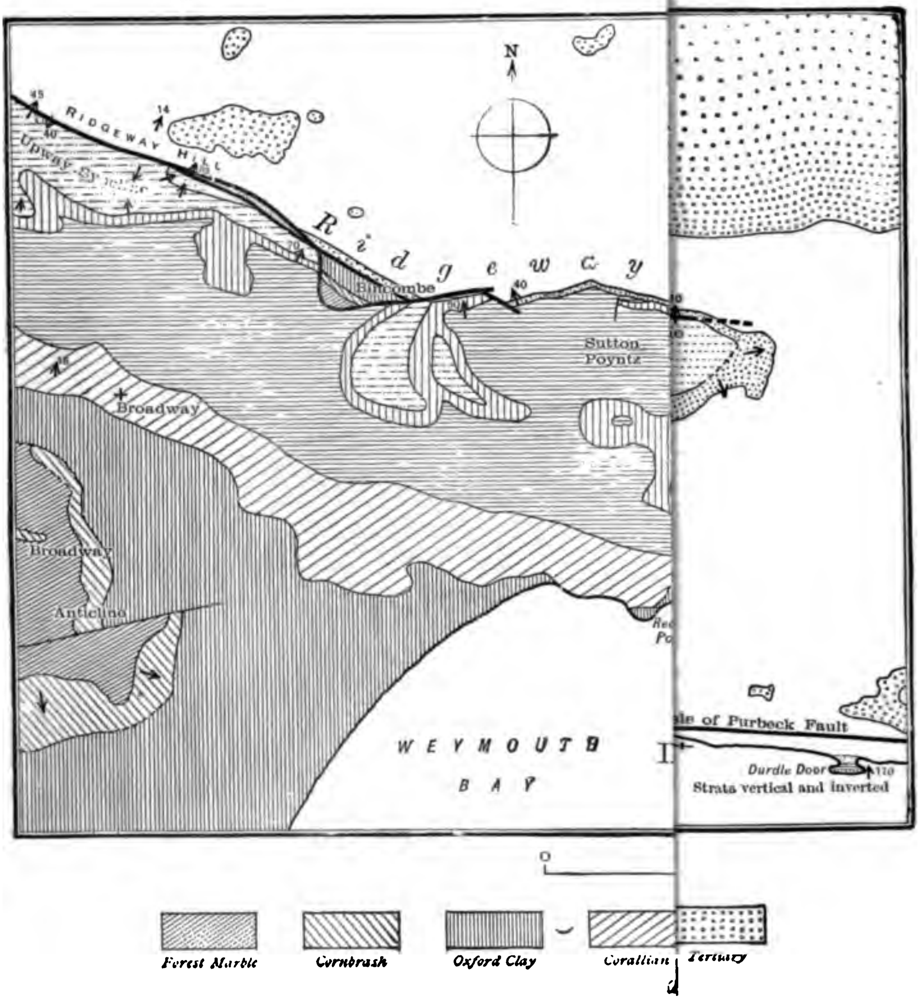
PLATE VI.



N
45
40
14
RIDGEWAY HILL
Upway Syncline
45
70
Ridgeway
Bincombe
20
40
Sutton Poyntz
45
Broadway
Broadway Anticline
Isle of Purbeck Fault
WEYMOUTH BAY
Durdle Door
110
Strata vertical and inverted
0
Forest Marble
Cornbrash
Oxford Clay
Corallian
Tertiary

nearly perfect parallelism between the Upper and Lower Cretaceous rocks, and no reason to suspect the existence of any intra-Cretaceous disturbances. The principal faults have already been described, and we need only now recall the apparent connection between the faulting and doming-up of the Kimmeridge Clay (p. 51). The general effect of the faults is to reduce considerably the height of the dome that would be caused by dip alone.

(2) *The Ringstead Post-Cretaceous Fold.*

The Upper Cretaceous rocks at White Nothe dip about east-north-east at 5°, but further inland at 12°. They then suddenly plunge down northwards at an angle of 75° near South Down Farm. Three hundred yards further west the dip is still as high as 40°, but six hundred yards from the farm it becomes quite gentle. As elsewhere pointed out (p. 186), the general effect of the movement has been to throw the strata into the form of a syncline with a sharp upturn to the south, and thus lead to the preservation of this long spur of Chalk. Though traces of the syncline can be detected for some four miles, it becomes quite shallow a short distance both east and west of the farm mentioned. The inclination of the Jurassic strata at Osmington Mills is of course due to an earlier disturbance, for Upper Greensand lies nearly horizontally upon them. Here, moreover, we get proof of the age of the earlier movement, for it affected not only the Jurassic rocks but the Wealden formation.

(3) *The Chaldon and Ridgeway Fault and Anticline.*

Chaldon (Plates VI. and VII.).

This disturbance commences three quarters of a mile east of Chaldon Herring as an arch in the Upper Chalk, rising gently up from the south, but descending at angles of 40° to 50° towards the north. The crest of the arch having been denuded away, the Wealden and Purbeck rocks are exposed, and in them also an anticlinal structure exists which might at first sight be attributed solely to the post-Cretaceous movement, though it results as a matter of fact from the superposition of this upon an earlier disturbance.

The proof lies in the relations of the Upper Greensand to the Wealden and Purbeck beneath, for not only does it rest on different parts of the Wealden formation, but it passes unconformably over the Purbeck rocks. It is clear therefore that these older formations had been uplifted and partially denuded before the Upper Greensand was laid down upon them. Further than this, we can infer what the structure in the older rocks was, by eliminating the dip due to the later movement. Thus, the Wealden Beds, near Chaldon, dip southwards at 8° to 12° faster than the Upper Cretaceous Rocks: hence this represents their dip before the later movement. Again, the Purbeck rocks, at the anticlinal axis, show a slight tendency only to turn over to the north, though the Chalk and Greensand resting upon them dip steeply in that direction; hence the Purbeck rocks must here have dipped at a steep angle southwards before the later movement, and must have been restored nearly to horizontality by it. On extending these observations, we find that the Wealden and Purbeck rocks fall into their proper positions as portions of the northern margin of the Osmington syncline, which is quite obviously a structure due to the earlier movement.

The inclination of the Chalk along the northern margin of the inlier ranges from 40° to 60°, but rapidly diminishes northwards. In four pits, however, about 200 or 300 yards south of the Tertiary area, the Chalk, though slightly inclined, is much shattered and traversed by a fault with a low hade to the north. The repetition of the structure in all the pits suggests that there may be a series of such faults in this tract of chalk, similar on a small scale to the great thrust-fault of Ballard Point.

Poxwell, Bincombe, and Ridgeway.

At Holworth the Chaldon fold runs a little north of the Greensand outcrop and then dies away in the Upper Chalk, but almost immediately the great faulted fold of Poxwell and Ridgeway starts into existence about 400 yards further south. That there is a fault here as well as a fold admits of no doubt, for the Upper Greensand and part of the Chalk are cut out for upwards of two miles. The only section in the latter worth noting occurs near Moigns Down Barn, where the Middle Chalk with numerous small overthrusts dip north at 40°. The Jurassic rocks here dip northwards at a steeper angle than the Cretaceous, from which we infer that they had a northerly dip before the Ridgeway fold was produced. This means that we have here touched an intra-Cretaceous anticline which lies on the north side of the intra-Cretaceous Osmington syncline.

Under White Horse Hill, for about a mile and a-half, the Upper Cretaceous sub-divisions all crop out in normal succession, so that there is no necessity to assume the existence of a fault. They dip at angles of 40° to 50° near the line of upturn, but fall to 5° at 400 yards from it. The Jurassic rocks, however, dip more steeply than the Chalk, and therefore had a northerly dip before the latter movement, a fact which enables us to trace the earlier anticline a step further. It diverges slightly from the post-Cretaceous fold westwards and finally flattens out near Sutton Poyntz.

From Sutton Poyntz westwards the Ridgeway Fault becomes remarkably complicated. The regular outcrops of the Upper Greensand and Lower Chalk are interrupted at the high road by a curving fault for two-thirds of a mile, but reappear nearly on the same line of strike at Bincombe, the fault thus taking a bite as it were out of the Chalk and Greensand outcrops. The Jurassic rocks in the concave southern side of this fault dip at 50° to 70° northwards, but turn over almost immediately to form the nearly level plateau of Chalbury. The structure resembles that of Ballard Point, except in the rapidity of this turn-over, and the fault is almost certainly an overthrust.

The Greensand dips at 40° to 50° at Bincombe, and its regular outcrop might have been taken to indicate a natural superposition, were it not faulted out for a long distance west of the village. In the rocks beneath it, moreover, a structure is revealed which, however explained, implies movements of most unusual character and magnitude.

The escarpments of Portland Stone both east and west of Bincombe overlook a low tract of Kimmeridge Clay, all being nearly horizontal, but near the Ridgeway fault they suddenly plunge down northwards at 50° to 70°. The outcrop of the stone then runs in a well-marked straight ridge at a distance of 100 to 200 yards from the Greensand, and nearly parallel to it, with the Lower and Middle Purbeck in proper sequence on its north side. So far, the structure resembles that of other parts of both the Ridgeway and Isle of Purbeck Faults, but under the village of Bincombe the ridge is suddenly interrupted, and in following the strike of it we step from Portland Stone on to Oxford Clay with Cornbrash and Forest Marble cropping out in due order below it. These strata dip at gentle angles, and of their correct determination there can be no doubt, for the Cornbrash has yielded *Pholadomya bucardium*, *Goniomya v-scripta*, *Lucina*, *Isocardia*, *Trigonia*, *Pecten*, &c. Their discovery is due to the Rev. O. Fisher, but they were first recorded by being shewn on the original one-inch Geological Survey Map, by H. W. Bristow.

The fault which throws these rocks against the Portland Stone west of the village seems by the form of the ground to run nearly north and south, but elsewhere the boundaries of the inlier are obscure, though the Cornbrash can be traced for 400 yards towards the Portland escarpment of Chalbury. Between the Cornbrash and Portland Stone there should be about 1,900 feet of strata in normal sequence.

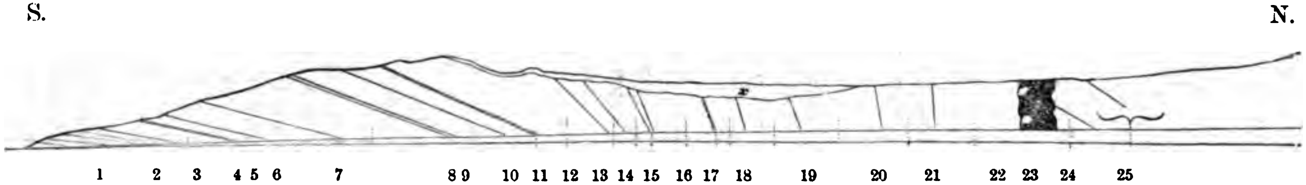
A similar complication occurs a little further west, along the Ridgeway Fault, but here, fortunately, the railway-cutting at the southern end of the Bincombe Tunnel has fully exposed the structure. The southern end of the cutting traverses Lower Purbeck rocks, dipping northwards at 20° to 26°; the Cinder Bed crops out close to the south side of a bridge over the line, and the Upper Purbeck succeed in their proper place on the north side of the bridge. Above them the Wealden Beds occupy the cutting for 120 yards, the dip gradually swinging round to north-east at an angle of 55°. At this point the cutting passes a nearly vertical fracture and enters Oxford Clay, thus jumping from the middle of the Wealden into Middle Oolites, and missing over a series of beds that can be hardly less than 2,000 feet thick. The Oxford Clay, however, occurs as a narrow "dyke" only, for 20 or 30 yards further on the cutting enters nearly vertical Lower, Middle, and Upper Chalk, while a little to the east of the railway a portion of the Upper Greensand also comes in in proper sequence at the base of the Chalk.

In the 50 years which have elapsed since the cutting was made, the clay-beds have become obscured, but the actual relations of the Oxford Clay to the strata on either side of it were observed by the Rev. O. Fisher while the works were in progress, and the following description and drawing of the section were furnished by him to the author of "A Guide to Dorchester and its

Fig. 180.

Section along the Weymouth and Dorchester Railway on the south side of Ridgeway Hill.

(L. L. B. Ibbetson and C. H. Weston.) Scale, 400 feet to 1 inch.



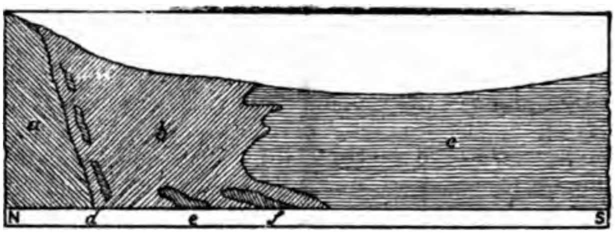
x Superficial Deposit
25. Chalk.
24. Upper Greensand.
23. Faulted mass of Oxford Clay, with blocks of Cornbrash.
22. White Sand.
21.
20. } Coloured sands and loams.
19. Grey, white and yellow sands with lignite } Wealden Beds.
18. Clays with *Unio* and lignite.
17. Indurated marl.
16. Sand-rock, clays, and marls, with *Unio*, &c.
15. Sand-rock.
14. Marl, sand-rock, and limestone, with *Cyrena*, Cyprides, &c. } Upper Purbeck Beds.
13. Laminated clays, with "beef,"
12. Clays, sand-rock, marls and limestone, with *Cyrena*, Cyprides.
11. Limestone with *Ostrea*.
10. Sand-rock and clays, *Cyrena*, Univalves, and Cyprides. } Middle Purbeck Beds.
9. Marls, sand-rock, and clays.
8. Sand-rock, Cyprides.
7. Sand-rock, marls and clays.
6. Variegated sandy clays, Cyprides.
5. Sand and clays.
4. Chert, *Valvata*, *Paludina*.
3. Sand-rock, clays and marls, with some chert. } Lower Purbeck Beds.
2. Sand-rock, *Perna*.
1. Marl-rock with seams of flint, *Perna*, *Cardium dissimile*, *Trigonia gibbosa*, *Pleurotomaria*, &c. } Portland Beds.

Neighbourhood."[*] "The writer having opportunities of watching the progress of the works, was aware of an oolitic clay appearing here as long ago as 1846, when the trial shafts were dug. He then found a piece of the shell of a Trigonia in the clay from the shaft; but when the cutting was commenced, *Gryphæa Dilatata* occurred in plenty with portions of other fossils of the Oxford Clay, and he was convinced of the identity of the clay. Experienced geologists, however, to whom he communicated the fact would scarcely credit the tale, but at last they were convinced by a personal inspection of the spot.

"During May 1849 the section appeared thus:—

FIG. 181.

Section showing the mode of occurrence of the Oxford Clay in the Ridgeway Cutting. (Rev. O. Fisher.)



"(*a*) Lower Chalk, nearly vertical, much crushed and hardened.

"(*b*) Oxford Clay, with what appear to be nodules of greensand engaged in it at (*d*). Also fossiliferous nodules at (*e*).

"(*c*) Wealden beds, nearly vertical, passing gradually into Purbeck beds to the south. The curious irregular line (*f*) is the junction of the two clays, which appeared very well defined."

To this account we may add that *Gryphæa dilatata, Modiola bipartita, Thracia depressa, Ammonites arduennensis, A. Mariæ, A. perarmatus (catena)* were collected by Mr. Weston from the Oxford Clay and identified by Mr. Sowerby.[†] As noted by Mr. Woodward,[‡] these fossils indicate that the upper and middle portions of the Oxford Clay are represented. Yet blocks of Cornbrash were found by Mr. Weston imbedded in the same mass of clay. The whole mass, therefore, has evidently been jumbled up.

Two theories to account for the structures here seen have suggested themselves. We may either suppose that the faults on either side of the Oxford Clay "dyke" are of different ages, the one intra-Cretaceous with a big downthrow south, and the other post-Cretaceous with a big downthrow north, so that the Oxford Clay stands as wedge between them;[§] or we may account for the whole structure, both of the Railway Cutting and of Bincombe, on the theory of an overthurst.

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[*] *Dorchester* (published by William Barclay in or after 1849). Anonymous, but, according to Mr. Fisher, written by the Rev. W. Barnes.

[†] *Quart. Journ. Geol. Soc.*, vol. iv., p. 250 (1848); vol. viii., p. 116 (1852).

[‡] *Jurassic Rocks* (Geol. Survey Memoir), vol. v., p. 20 (1895).

[§] *See* W. H. Hudleston, *Proc. Geol. Assoc.*, vol. xi., p. lii. (Report on the Eastern Excursion, 1889), and H. B. Woodward, *Jurassic Rocks of Britain*, vol. v., p. 20.

The first theory involves the assumption that the older fault was of such magnitude as to bring Wealden beds against Oxford Clay, a throw of about 2,000 feet. But a fault of anything like this size is unknown in the Secondary Rocks of the South of England. Moreover, to account for the Bincombe inlier by any system of normal faulting we have to suppose that a pyramidal mass of Oxford Clay, Cornbrash, and Forest Marble was pushed up a distance of about 1,900 feet through but little disturbed Kimmeridge Clay, a most improbable structure.

The second theory also involves much speculation, but presents less difficulties. In it we attribute the whole of the faulting to overthrusting produced by the Ridgeway movement. In the first place we know that the Upper Cretaceous Rocks in this district rest uncomformably upon a floor composed of all the members of the Oolitic group, and the question naturally occurs whether they may not rest on Oxford Clay under Bincombe Down. Some idea of the probability of this being so can be formed by referring to the mapping of the country between Bridport and Dorchester, where in three different localities, namely, East Compton, Chilcombe, and the Bredy Valley, the Upper Greensand is shown to rest directly upon that rock, or upon still older Oolitic beds. This results partly from the general dip of the Oolitic rocks, but especially is due to a large intra-Cretaceous fault north of Abbotsbury, which has a downthrow south of not less than 600 feet. Evidence is not wanting that a similar succession may occur under the Chalk of Ridgeway. Close up to the Ridgeway fault a syncline introduces the Middle Purbeck strata near Upway, and along the fault itself there are several indications that the beds are turning sharply up to the north, or in other words, that we are approaching an intra-Cretaceous anticline, hidden under the Chalk. Thus the Portland stone rises to the surface in two places on the north side of this syncline, while the Wealden Beds of Ridgeway seem, from the fact that they are less highly inclined than the Chalk, to have had a southerly dip before the Ridgeway fold was produced. Moreover, the large intra-Cretaceous fault near Abbotsbury ranges towards Blackdown, and might quite conceivably pass near Bincombe Down, or be replaced in that neighbourhood by other southerly downthrows. Taking these circumstances into account, we find no difficulty in supposing that the Oxford Clay may lie next below the Upper Cretaceous Rocks not far north of Bincombe Tunnel. Here, therefore, we have an alternative source, not only for the Oxford Clay of the "dyke," but for the Oxford Clay, Cornbrash and Forest Marble of the Bincombe inlier.

We still have to account for the appearance of these rocks to the south of their sub-Cretaceous outcrop. The Ridgeway fault not only belongs to the same age as the Isle of Purbeck movement, but resembles it in so many essential points, that we may infer that it also is a "thrust" and not a normal fault. In the latter case the Chalk on the north side would have sunk relatively to the Oolites on the south side; but in the case of a thrust the Chalk must have been forcibly pushed over the Oolites, and elevated rather than sunk relatively to them, the movement resembling that which took place at Ballard Point, with this difference only, that there Chalk was thrust over Chalk.

In the Ridgeway thrust we have repeatedly seen that the fracture approximately followed the Upper Cretaceous base, sometimes exactly, but more often running a little above it. To account for the protrusion of the Oxford Clay we have only to suppose that a part of the fracture locally ran below the Upper Cretaceous base, and that some of the floor was then caught up and carried bodily southwards with the Cretaceous rocks. This seems the less improbable when the softness and "greasiness" of the Oxford Clay are taken into account.

If this view is correct the Kimmeridge Clay and Portlandian rocks ought to underlie the Forest Marble, Cornbrash, and Oxford Clay of Bincombe; the Portlandian scarp west of that village keeping its course under the over-thrust mass and joining itself up with the outcrop east of that village. Borings would not improbably decide the question.

On this theory we can dispense with the almost impossible system of faulting by which it was sought to account for the Bincombe inlier on the original map. Almost the only serious objection to it lies in the distance over which the thrust mass must have travelled. The exact source is of course unknown, but it seems unlikely to have been less than half a mile north of the present position of the inlier.

Portisham.

From Ridgeway westwards, the Ridgeway fault is sufficiently illustrated by the map. The Chalk dips northwards, at high angles, close to the fault; the Portland and Purbeck rocks, on the other hand, dip south, and not, as heretofore, towards the fault. Westwards the strata are less folded, but the fault is considerable, as far at least as Portisham, where it throws Chalk and Greensand in succession against Kimmeridge Clay. It dies out, however, completely about half a mile west of Portisham, and at Abbotsbury no trace can be found of either fault or fold.

(4) *The Litton Cheney Fault.*

This, the last of the series of post-Cretaceous disturbances within the area under description,* comes into existence where the Ridgeway fault dies out, but about 3½ miles further north. Like the Chaldon fold, it commences as an arch in the Chalk and Upper Greensand, the dip on the northern side ranging up to 35°, but it exhibits this structure only at its eastern end, near Long Bredy, for throughout the remainder of its course it is represented by a fault only, by which Chalk and Greensand are thrown against Kimmeridge Clay and Corallian Rocks, the arch having been completely denuded away; in fact the Chalk and Greensand dip gently southwards and eastwards near the fault, while the Corallian dip southwards at 30° to 45°. Less than a mile west of Litton Cheney the disturbance dies away. The Kimmeridge Clay of Litton Cheney lies in a syncline, which we know to be partly of an earlier age by the fact that it does not affect the Upper Cretaceous Rocks at Long Bredy. The steep southerly dip of the Corallian is, therefore, due to two movements, each tending to tilt the beds in the same direction.

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* A fault and anticline at Winterborne referred to by M. Barrois (*Terrain Crétacé Supérieur*, p. 87) does not come within the area. It seems to fall nearly into the line of the Litton Cheney fault, and is also of post-Cretaceous age.

The fault differs from those previously described in the occurrence of this southerly dip on its north side, and though the arch at Long Bredy resembles those caused by the post-Cretaceous movements, yet even here the structure can be explained better by normal faulting than by overthrusting.

INTRA-CRETACEOUS DISTURBANCES.

These are distinguished from all the later movements by the fact that they do not affect the Upper Cretaceous Rocks. The newest strata which can now be seen to have been disturbed by them are of Wealden age, but, as already mentioned (p. 132), there is reason to think that the Lower Greensand also was affected, and that the movement took place chiefly therefore in the period immediately anterior to the Gault. The effects of the disturbances are not recognisable in Purbeck, but are suggested by the pronounced erosion at the base of the Gault near Lulworth, and become most conspicuous in the western part of the district. Nowhere are they better displayed than in the grand section at White Nothe described by Mr. Fisher in 1854,* and in the cliff near Osmington Mills. (Fig. 159 and Plate IX.)

The anticline to which the tilting of the older strata in these cliffs is due runs by Osmington Mills, where the curious complication of faults described on p. 31 occurs. It ranges a little north of west, and though extremely sharp at the "Mills" flattens out quickly westwards, but to the south and east of it a series of flexures can be detected among the reefs of Corallian rocks at low water. This anticline is still in part overspread by Upper Cretaceous Rocks, but denudation has made a sufficient number of gaps in the newer series to disclose the structure of the older strata to an unusual extent. Thus a glance at the map shows that the position of the outcrop of Portland Stone beneath the Chalk and Greensand could be fixed with considerable accuracy anywhere between White Nothe and Osmington.

The Upton syncline, which succeeds the Osmington Mills anticline on the north, is no less obviously of intra-Cretaceous age. This again is succeeded by an anticline which has already

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* *Trans. Cambridge Phil. Soc.*, vol. ix., p. 556.

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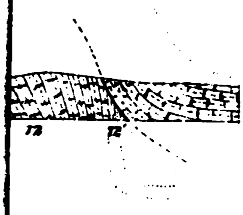

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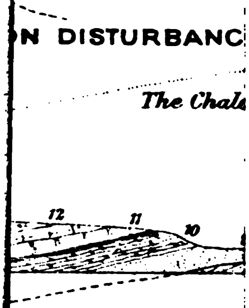

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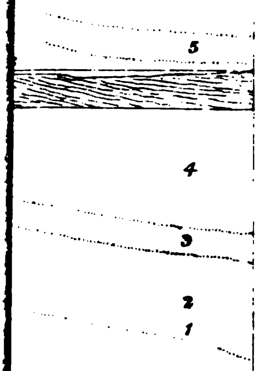

been shown to have existed before the Ridgeway Fault was produced, but which has been disguised by the energy of that movement (p. 221).

The Broadway anticline,* which forms the key to the structure of the whole Weymouth promontory, falls exactly into the line of the Osmington Mills folds, and differs from them only in being a broad, flattened, and slightly-faulted arch, instead of a sharp crumple. The Kimmeridge Clay outcrop runs without interruption along the northern limbs of both anticlines, and both to the east, near Osmington, and to the west, near Abbotsbury, is overlain by nearly horizontal Upper Cretaceous beds. On the north it is succeeded by the syncline which was detected in the Kimmeridge Clay near Abbotsbury and Portisham and in the Purbeck Rocks near Upway.

At Abbotsbury there occurs one of the largest intra-Cretaceous faults of the district. It falls nearly into the line of the Ridgeway fault, but is a downthrow south of about 600 or 700 feet. Were the Greensand and Chalk displaced to nearly this extent they would be thrown down under the village of Abbotsbury. On the contrary, as far as can be judged in the labyrinth of landslips, they are not shifted by it at all.

Following the Upper Cretaceous escarpment northwards, we find a fault introducing the Oxford Clay into the Bredy valley, a syncline in the Kimmeridge Clay and Corallian Rocks at Litton Cheney, and another large southerly downthrow at Shipton Gorge, all undoubtedly of pre-Gault age. All these folds and faults run approximately east and west, and very nearly parallel to the later disturbances, though it is possible occasionally to see that the one set has crossed the other obliquely, as described on p. 222.

Explanation of Plate VII.

13. Tertiary Beds.
12. Upper Chalk.
(12′ *Belemnitella*-zones).
11. Middle Chalk.
10. Lower Chalk.
9. Upper Greensand and Gault.
8′ Variegated Beds } Lower
8. Atherfield Clay. } Greensand.
7′ Wealden Shales. } Wealden
7. Hastings Beds. } Beds.
6. Purbeck Beds.
5. Portlandian.
4. Kimmeridge Clay.
3. Corallian.
2. Oxford Clay.
1. Cornbrash.

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* In assigning the earlier age to the Broadway anticline I am compelled to differ from the late Sir Joseph Prestwich, who argued from the distribution of the gravels that this anticline and the denudation which ensued upon its formation were of quaternary date. (*Quart. Journ. Geol. Soc.*, vol. xxxi., p. 43).

An alternative explanation of the occurrence of the gravels alluded to is given on p. 200.

CHAPTER XVI.—PHYSICAL GEOGRAPHY.

Having noted in the foregoing chapters the principal features and the geological structure of the Dorset coast, we will endeavour now to trace the connection between them. We shall find that the denudation by which those features have been produced has been due to and directed by the later of the several series of disturbances we have described.

It has been shown elsewhere* that the rivers of this part of England may be grouped into (1) two main lines of drainage following the east and west synclines of the London and Hampshire basins, and (2) a number of tributaries flowing from the anticlinal axes which separate those synclines. Thus the Thames and the Kennet follow the London syncline pretty closely from end to end, and are fed from the south by streams which rise in the Wealden anticline. The Frome plays the same part for the Hampshire basin, and though the greater part of the drainage-system of the original Frome has been destroyed by the sea, we may infer that it also followed the synclinal trough eastwards, for the Solent and arm of the sea at Spithead fall exactly into the position which we should have assigned to it by analogy with the Thames.†

It is worthy of remark, moreover, that in both the London and Hampshire synclines the deepest part of the trough lies towards the southern margin of the Tertiary areas in consequence of the form assumed by all the post-Cretaceous folds, and that both the Thames and the Frome accordingly hug the southern sides of their respective synclines, and receive their largest tributaries from the long dip-slopes on their northern banks.

The tributaries of this ancient Frome therefore were the rivers which flow south from the Wealden anticline on the one side, and north from the Isle of Wight and Isle of Purbeck anticline on the other. Traced right round, the water-parting of the Frome must have run somewhat as follows:—From the neighbourhood of Hastings it followed the main anticline of the Wealden area westwards, which throws off to the south the rivers Ouse, Adur, and Arun. Thence it trended northwards along the anticline which runs near the northern margin of the Hampshire Downs and from which flow the Test and the Itchen, and thus reached the well-known Kingsclere anticline where the Avon takes its

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* *Geology of the Isle of Wight* (Memoirs of the Geological Survey), 2nd Ed., p. 248. *Proc. Geol. Assoc.*, vol. xiv., p. 406 (1896).

† This fact was first recognised by the Rev. W. Fox (*Geologist*, vol. v. p. 452, 1862). Subsequently Sir John Evans came to the same conclusion from a consideration of the distribution of the gravels (Presidential Address, *Proc. Geol. Soc.*, 1874-75, p. 71).

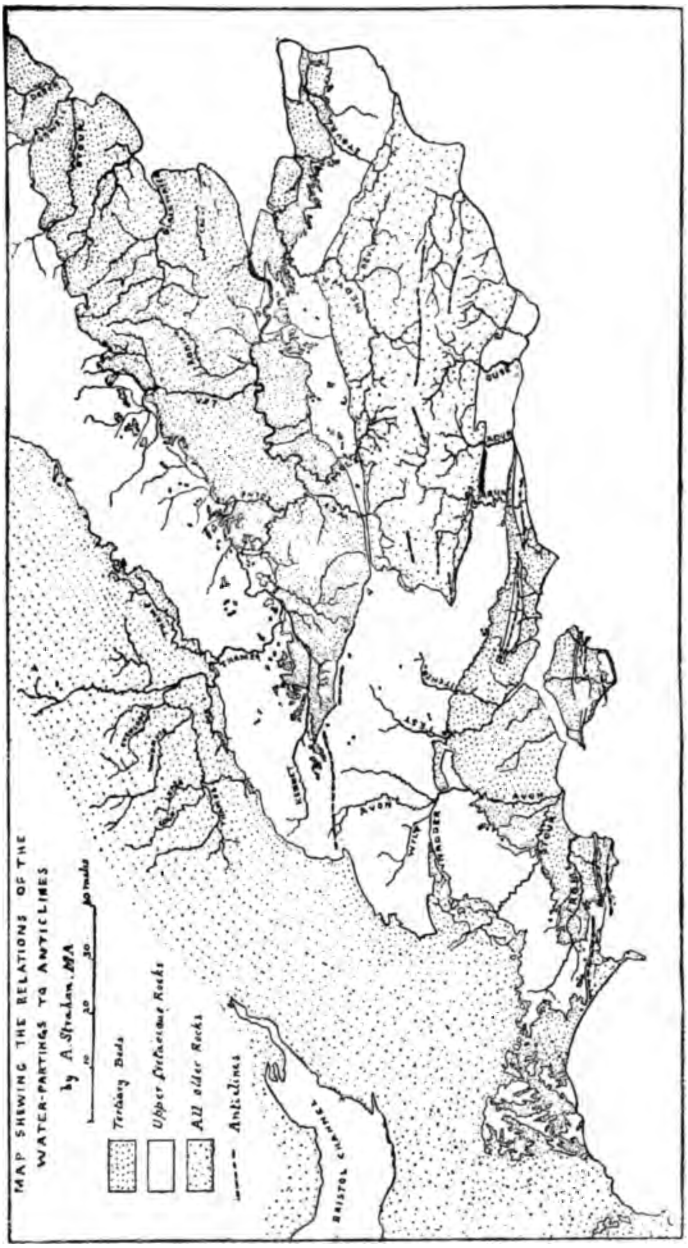

FIG. 183.—Map showing the relations of the water-partings to the anticlines in the South and South-east of England. (*Reproduced from the Proc. Geol. Assoc., vol.* xiv.).

rise. Here the water-parting touches the margin of the area occupied by Upper Cretaceous Rocks, and even passes beyond it so as to include a bit of Jurassic ground within the drainage of a tributary of the Frome known as the Stour.[*]

The water-parting on the south side of the Frome basin runs by Winterborne Common to the Ridgeway anticline, which it follows close up to its termination at Chaldon. It then strikes south-eastwards by East Lulworth, and West Tyneham, and so gains the Isle of Purbeck anticline. This it followed eastwards at least as far as the Isle of Wight, for the streams in that island have been shown to have been tributaries of the ancient Frome[†], and the Swanage Brook must, like them, and like the Corfe Castle stream, have also flowed northwards to the Frome before the drainage-basin was encroached upon by the sea.

Striking though this coincidence of water-parting with anticline appears when traced upon a geological map, it is not so obvious upon the ground, for though the anticlines originally formed the most elevated regions they do so no longer. In the majority of cases the Chalk has been denuded from the crest of the arch and the softer Jurassic rocks beneath exposed to waste, with the result that the area of greatest upheaval is nevertheless the area of least elevation. The degradation of the anticlinal region depended upon and kept pace with the deepening of the river-valleys, and as it proceeded the escarpments of Chalk, crossed at regular intervals by the transverse valleys, came more and more into relief. Such was the origin not only of the well-known features of the Wealden area with the dominating scarps of the North and South Downs, but of the anticlinal region of the Isles of Wight and Purbeck also, with their long central chalk-ridge forming an exact counterpart of the North Downs.

So far as we can judge, however, from the small remnants of this southern anticline which the sea has spared, it was both narrower and sharper than that of the Weald, for the strata tend to become horizontal more rapidly than in Kent and Sussex, while at the same time the upturn on its north side is not only far more abrupt, but accompanied by the peculiar faults described in a previous chapter. It seems possible, however, that the movements may have attained their greatest energy in the north-west corner of this anticlinal region (Isle of Purbeck), as they did in the north-west corner of the Wealden anticline (Guildford). It resulted from the narrowness of the anticline that its crest lay close to the synclinal axis, and the streams from it were consequently all small.

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[*] Though its basin does not fall within the area described in the Memoir, a few words may be devoted to explaining this peculiarity in the course of the Stour. The river forms a close parallel to the Thames above its junction with the Kennet, as may be readily seen by an inspection of the map forming Fig. 183. For this part of the Thames may be regarded from a geological point of view as a tributary to the main line of drainage which follows the syncline, and, like the Stour, it rises in the Jurassic area far westward of the Chalk-escarpment. Both rivers therefore rise in an area of little elevation and flow towards and through an elevated plateau. Their history is the same as that of the rivers of the Wealden area; they were initiated by the tilting of the Chalk and formed the means of draining the long dip-slopes that were brought into existence thereby. Since their initiation the Chalk escarpment has receded under the influence of subaerial denudation, in the case of the Stour not less than 10 or 15 miles, and in that of the Thames not less than 30 miles; but the rivers retained their original courses. The amount of denudation performed is comparable to that of the Wealden area.

[†] *Geology of the Isle of Wight* (Memoir of the Geological Survey), 2nd Ed., pp. 223, 230, and chap. xv.

The apparently anomalous course pursued by the tributaries of either the Thames or the Frome is admirably illustrated at Corfe Castle. The area there drained consists of a strike-valley which has been excavated along the outcrop of the Wealden and Purbeck strata, and which leads without interruption down to the sea, both eastwards and westwards. The brooks nevertheless turn northwards, traverse the chalk-range in two closely adjoining defiles, unite in the Tertiary plain beyond it, and so join the Frome. They form therefore an exact counterpart of the rivers of the Weald, which also leave the obvious route to the sea along the low Wealden area and turn either north or south across the chalk-plateau.* They began to flow when the chalk-arch was intact, and once established in their courses retained and deepened them, thus providing egress for the material denuded from the anticlinal region.

The crest of the Ridgeway hills lies on the north side, but quite close to the crest of the Ridgeway anticline, denudation not having yet sufficed to cut back the chalk-scarp so far as in either the Weald or the Isle of Wight. Here, therefore, the most prominent physical feature nearly coincides with the water-parting. The streams flowing south from it pass over Jurassic rocks to Weymouth Bay, and it is interesting to note that they cross and quite ignore the sharp folds into which those rocks have been thrown. These folds, as we have seen, were formed at an earlier age than the Ridgeway and Isle of Purbeck anticlines, and whatever inequalities of surface they produced were planed off before the deposition of the Gault, and played no part in determining the courses of the modern rivers.

The streams thus thrown off by the Ridgeway anticline may be reasonably supposed to have united into one line of drainage in the area now occupied by Weymouth Bay, and to have reached the sea somewhere between White Nothe and Portland Island. This island is the sole remnant of an escarpment which must have fringed the Weymouth anticline on the south, and which, judged by the strike of the rocks on Portland, must have run direct from the island to White Nothe. Somewhere, however, the escarpment must have been breached by fluviatile erosion to allow the escape of the water of the eastern end of the Weymouth anticlinal region to the sea, and it was by the widening of this breach and by marine erosion of the softer strata behind it that Weymouth Bay came into existence.

The form of the ground on its northern bank suggests that the "Fleet River" also flowed into Weymouth Bay, in which case it must have separated Portland Island from the mainland, but we have insufficient data for speculating on the form of the land that lay south of the Chesil Beach. Near Abbotsbury we reach the water-parting of this southward and eastward running drainage-system, and find the streams all trending southwards and westwards.

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* W. Topley, *Geology of the Weald* (Memoirs of the Geological Survey). The analogy between the drainage-systems of the two areas was first noticed by Mr. W. H. Hudleston in 1882.—*Proc. Geol. Assoc.*, vol. vii., p. 379.

We have seen that the features of the Dorset and Hampshire coast were due firstly to the subaerial denudation of an anticlinal region analogous to the Wealden area, and secondly to the partial destruction of that region, and the invasion of the synclinal region north of it by the sea. Access to the syncline by the sea was no doubt first gained by way of the estuary of the ancient Frome (or, as Sir John Evans called it, "the River Solent"), which must have lain somewhere east of Spithead; but as denudation proceeded the deepest of the transverse valleys made by the southern tributaries of the Frome became available, and by the widening of one or more of these a portion of the southern water-parting, still recognisable in the Isle of Wight, was separated from the main land. The destruction is still proceeding, and were there a transverse valley on the west side of the Isle of Purbeck[*] the insulation of that tract and the production of an exact counterpart of the Isle of Wight would be merely a matter of time.

The exact date at which Purbeck was separated from the Isle of Wight cannot be fixed, but the sequence of events seems to have resembled that which led to the insulation of Barry Island on the coast of Glamorganshire. There the sea, after encroaching on an estuary, broke across the water-parting and insulated a portion of it. The irruption was the direct consequence of a gradual subsidence of the land of not less than 55 feet, and has been proved to have taken place in late Neolithic times, the evidence consisting in the existence of submerged land-surfaces and peat-beds, and the occurrence in one of the latter of a polished flint-implement.[†] Similar submerged peats have been revealed from time to time in many parts of the coast, and recently in the Southampton estuary, where also there occurred Neolithic remains.[‡] The insulation of the Isle of Wight therefore cannot be of later, though it may be of earlier date than Neolithic times, but it was of course long subsequent to the initiation of the river-system of the South of England.

This system we have shown to have been the direct outcome of earth-movements which were renewed from time to time from the Eocene up to an early Pliocene period. That any physical features can have survived through the whole of the Tertiary Epoch is scarcely conceivable, and we know, moreover, that the most energetic movements took place in post-Oligocene times. On the other hand, that the movements had been completed before the Pliocene period closed, seems proved by the absence of any Pliocene beds in the Hampshire and London basins.*

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[*] The stream known as Luckford Lake almost effects the breach required to complete the resemblance to the Isle of Wight. The absence of a more important tributary here is due to the influence of the Ridgeway disturbance, for the water-parting leaves the Isle of Purbeck anticline at this point to cut across country to Ridgeway.

[†] *Quart. Journ. Geol. Soc.*, vol. lii. (1896), p. 474.

[‡] T. W. Shore, *Rep. Brit. Assoc.*, 1888 (Bath), p. 672, and *Proc. Hampshire Field Club*, No. 3, p. 43 (1889).

The mode of occurrence of the Plateau gravels, deeply denuded as they have been, proves that the rivers had already been established in their present courses, for these deposits frequently run along, and down the sides of valleys, which closely coincide with the valleys of the present day.† They mark, therefore, a stage in the excavation of the valley-system, but not its initiation. We may infer then that the system first came into existence in post-Oligocene times, that its excavation was temporarily interrupted during the submergence indicated by the occurrence of Pliocene marine deposits at a high level (Lenham, &c.), but that it was subsequently renewed, and is still in progress along the lines originally due to the post-Oligocene disturbances.

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* C. Reid, *Pliocene Deposits of Britain* (Memoirs of the Geological Survey), 1890, p. 69.

† A fact noted by Mr. Codrington in his admirable account of these deposits, *Quart. Journ. Geol. Soc.*, vol. xxvi., p. 528 (1870).

CHAPTER XVII.—ECONOMIC GEOLOGY.

Building Stones.

Though most of the Jurassic limestones have been used locally, the only building-stones of any value are those obtained in the Portland and Purbeck formations. The Portland Stone is still extensively quarried on Portland Island, and was formerly worked at Portisham and Upway, but more energetically in the cliffs between the St. Alban's and Durlston headlands, where it was commercially known as "Purbeck-Portland." The Lower Purbeck limestones have been quarried at Portisham, but become worthless in the Isle of Purbeck, where, on the other hand, the Middle Purbeck stone-bands have been in requisition from time immemorial. The Upper Purbeck division furnishes the well-known "Purbeck Marble," or *Paludina*-limestone, which takes a high polish, and has been employed for columns and other interior work in many cathedrals. Though recognisable at Mupe and Worbarrow Bays, the band has not been worked in the western part of the Isle of Purbeck, but from near Swanage to Kingston the old quarries are almost continuous. It has been employed of late years in the interior of the new church at Kingston. For a detailed account of the composition, durability, and employment of the Purbeck and Portland limestones, the reader is referred to "The Jurassic Rocks of Britain" (Memoirs of the Geological Survey), vol. v., chap. xvi. (1895). Analyses of the Portland Stone are given in vol. ii. of the Memoirs, part 2, p. 691 (1848).

Ornamental Stones.

Septaria from the Oxford Clay of Radipole Back Water, when cut into slabs and polished form suitable tops for fancy tables. Agates are picked up on the Chesil Beach.

Road Metal.

The principal local sources of road-metal are the Plateau Gravel, the angular flint-gravel of the chalk-downs and the Tertiary (Bagshot) gravel of Blackdown and Bincombe, but the Upper Chalk has been so much hardened along the Isle of Purbeck fault as to form a fairly durable limestone-metal. The Forest Marble and the refuse from the quarrying of Portland and Purbeck limestones are also used locally, but the principal roads are mended with stone brought from a distance.

Lime, Marl, and Cement.

Most of the limestones from the Chalk down to the Forest Marble have been locally burnt for lime, but the first-named more extensively than any of the others. The pits in the upper beds of the Chalk in the Isle of Purbeck yield both road-metal and limestone suitable for burning; most of those in the lower beds, on the other hand, have been opened in the Middle Chalk which has been burnt, and in the Chalk Marl which used to be spread upon the land, but is seldom employed for the purpose now. The Chalk of the downs from Lulworth to Dorchester and westwards has not been similarly hardened, and is used chiefly for burning.

Cement has been manufactured from the *Belemnitella*-Marl of the large quarry near Church Knowl, from Lower Purbeck limestones at Upway, and from the argillaceous limestones in the Kimmeridge Clay of Hen Cliff (p. 55);* formerly the Broad Bench stoneband in Kimmeridge Bay was employed for the same purpose. The more argillaceous limestones form a natural hydraulic cement when burnt, but others require to be mixed with clay in suitable proportions.

Gypsum and Alum.

Gypsum occurs in the Lower Purbeck strata of Durlston Bay, and was once worked to a limited extent.† It occurs, however, in incontinuous masses of no great extent, and though lumps fall out on the shore it is no longer collected, except for occasional use in rockeries.

Alum was obtained from Kimmeridge Clay in the early part of the last century, as mentioned on p. 54, and from the spoil-heaps of the Tertiary Clays near Corfe Castle (p. 192).

Phosphatic Nodules.

Casts of fossils in phosphate of lime occur everywhere in the Chloritic Marl, and less abundantly in the Upper Greensand, but have never been worked. The percentage of phosphoric acid is not high, and the extraction of the nodules would be costly. Similar nodules are found in small quantities in the Kimmeridge Clay and Portland Stone, according to Mr. Woodward.‡ Buckland records coprolites in the Corallian Oolite at Osmington.§

Brick Clay.

The Oxford Clay is almost the only source of bricks in the Weymouth area; the mottled clays in the Wealden Beds have been used near Swanage, and the Reading Beds at Broadmayne and Winfrith. The well-known pottery clays in the Bagshot Beds of Corfe are described on p. 192.

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* B. Green, *Kimmeridge Shale, its Origin, &c.*, 1886, p. 21.

† *See also* Englefield's *Isle of Wight*, p. 19.

‡ *Jurassic Rocks of Britain*, vol. v., p. 322.

§ *Trans. Geol. Soc.*, ser. 2, vol. iii., p. 232.

Iron Ore.

The Abbotsbury Iron-ore, described on p. 39, has been tried but never worked.

Oil Shales.

The Kimmeridge "Coal," though still used as fuel in the village, has not been profitably worked for export of late years. The older workings are confined to the neighbourhood of Hen Cliff, but the same or a similar seam has been proved in a shaft and several bore-holes at Portisham by the late Mr. Manfield. The various uses to which the shale has been put are described on pp. 53, 54.

Principal Springs.

Ullwell; a copious spring from the Lower Chalk north of Swanage, used for the supply of that town.

Studland Bay; in the foreshore of Upper Chalk on the south side of the bay.

Blashenwell; this spring from the Purbeck rocks formerly deposited calcareous tufa (p. 210).

Church Knowl, half a mile west of; from the base of the Chalk.

Worbarrow Bay; chalybeate springs in the Lower Greensand.

Arish Mell, south of East Lulworth; from vertical Upper Chalk, about 20 feet above sea-level.

West Lulworth; copious springs at high-water mark in the north side of the Cove, and a spring with a minimum outflow of 200,000 gallons a day from the Chalk 300 yards further west and 40 feet above sea-level.

Ringstead, Spring Bottom near; copious, from base of the Chalk.

Osmington Mills, 400 yards north of; from Upper Greensand.

Sutton Poyntz, Spring Bottom near; copious, from Middle Chalk; used for the supply of Weymouth.

Galton, near Owermoigne; copious, issuing from Reading Beds, but probably having its source in the Chalk.

Broadmayne, half a mile east of; at junction of Chalk and Reading Beds.

Upway; copious, from base of Portland Stone; known as the Wishing Well.

Radipole Spa; a medicinal spring containing 34 grains per gallon of chloride of sodium.*

Portisham; copious, from the Ridgeway Fault.

Little Bredy, half a mile south-west of; from the Upper Greensand. These springs are said to "break" simultaneously with the "wherry" at Winterborne Abbas.†

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* *Trans. Geol. Soc.*, ser. 2, vol. iv., p. 49. Explanation of Plate.

† "The spring [of the Winterborne] is, by the country people, called the Wherry, and is said to burst with great noise, generally about November, sooner or later, as the season is more or less rainy; for in dry seasons it has been known not to break out for three or four years together. . . . It is generally dried up soon after Midsummer, except the season be wet."—Hutchin's *History of Dorset*, 3rd Ed., 1863, vol ii., p. 196.

Little Bredy, Bride Head; from the top of the Upper Greensand. The lowering of the water in the lake at Bride Head is said to affect the flow from the Portisham Spring.

Long Bredy; copious, from the base of the Chalk.

Litton Cheney; from the Upper Greensand; used for the supply of Bridport.

Do., 250 yards north of the Church; from the fault between Chalk and Corallian rocks.

APPENDIX

List of Books, Papers, Maps, &c., on the Geology, Mineralogy, and Palæontology of Dorset.

By W. Whitaker, F.R.S. (1761–1873) and A. Strahan, M.A. (1874–1898).

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EOLOGICAL MAP O
AND THE NEIGHBOU

Scale—

0 1 2 3

UPPER

g^{14} *Purbeck Beds*

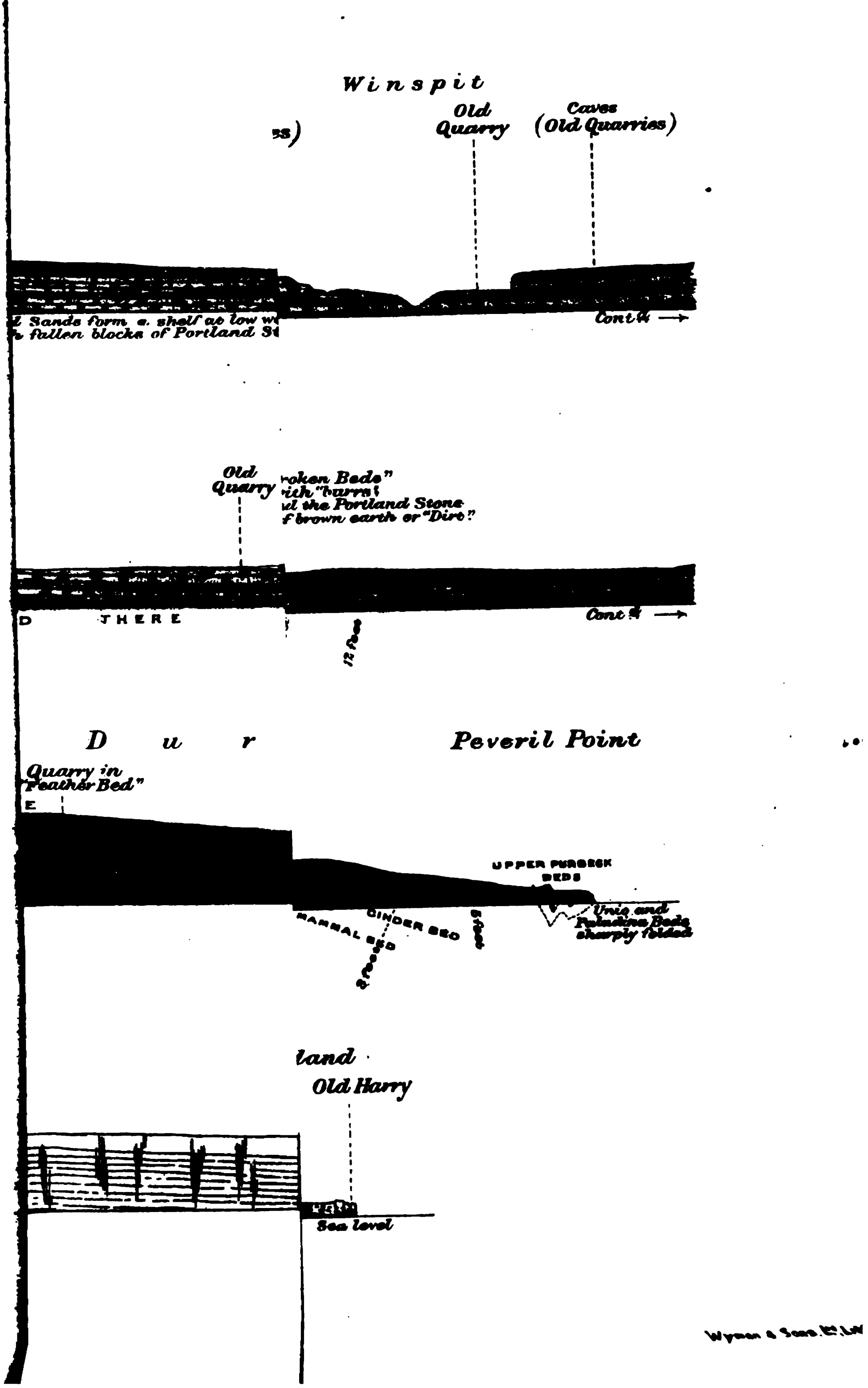
g^{13} *Portland Beds*

y

g^{12} *Kimmeridge Clay*

tion
Bacon
Hole
BEDS
PURB
ITE SEPTAR
WITH
egula

of Purbeck and Weymouth
Plate XI.



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